FIELD TEST OF TWO SPILL TREATING AGENTS

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by

Seakem Oceanography Limited
P.O. Box 696
Dartmouth, Nova Scotia
B2Y 3Y9

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ABSTRACT

Logistical services in support of a field operation to test the effectiveness of two new oil spill treating agents were provided. Elastol, which imparts a viscoelastic property to oil, and a liquid demoussifier/demulsifier (Brand M) were applied to ten test slicks laid midway between Nova Scotia and Sable Island. Observations of the physical characteristics of the treated slicks and chemical analysis of oil samples taken from them at time intervals ranging from one to six hours indicate that both agents are at least as effective as they have been shown to be in previous laboratory and large-tank tests. Application of the demoussifier in concentrations ranging from 250-4000 ppm effectively prevented the formation of water-in-oil emulsions and broke up pre-existing emulsions. When applied at levels between 1000 and 9000 ppm, Elastol was found to increase the viscoelasticity of crude oil to a greater extent than was expected on the basis of results of laboratory tests. Application effects were not noted with either product. Due to weather conditions at the time of the field trials, it was not possible to determine the effect of the treating agents on the ability to recover the oil.

RÉSUMÉ

Les services logistiques visant à appuyer les opérations menées sur le terrain pour tester l'efficacité de deux nouveaux agents de traitement des déversements d'hydrocarbures ont été fournis. L'Elastol, qui confère au pétrole une propriété viscoélastique, et un agent désémulsionnant liquide (Brand M) ont été appliqués à dix nappes d'essai déversées entre la Nouvelle-Ecosse et l'Île de Sable. Les observations des caractéristiques physiques des nappes traitées et l'analyse chimique des échantillons d'hydrocarbures prélevés dans ces nappes à des intervalles de temps variant d'une à six heures indiquent que les deux agents sont au moins aussi efficaces que l'indiquaient les résultats d'essais précédents en laboratoire et en gros bassin. L'application de l'agent désémulsifiant en concentrations variant de 250 à 4000 ppm empêchait, de façon efficace, la formation d'émulsions eau dans huile et fractionnait les émulsions préexistantes. Appliqué à des concentrations variant de 1000 à 9000 ppm, l'Elastol augmentait la viscoélasticité du pétrole brut plus que le laissaient prévoir les résultats des essais en laboratoire. Les effets des applications n'ont pas été inscrits pour aucun des produits. En raison des conditions atmosphériques au moment des essais sur le terrain, il a été impossible d'établir avec précision l'effet des agents de traitement sur la capacité de récupérer le pétrole.

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1.0 INTRODUCTION

Two chemical agents to modify the physical properties of spilled oil recently have been introduced to aid in the recovery of petroleum hydrocarbons spilled at sea. In this study, the effectiveness of these in modifying oil spill behaviour were tested in the field.

Elastol [1] is a proprietary formulation that comprises a high molecular weight isobutylene polymer coated with a metallic soap. These compounds are insoluble in water, but form solutions in non-polar solvents which exhibit viscoelastic behaviour. Oil slicks floating on water that have been so treated have enhanced cohesive forces and thus should be more easily contained, collected and separated from the water. Small scale laboratory tests of their effect on the physical properties of oil have been undertaken by the manufacturer (Waters and Haderman 1987) as well as by Environment Canada in a meso-scale outdoor tank test (Bobra et al. 1987a). The results of these studies show that the elasticity of various oils is indeed enhanced and that tank-confined slicks have been significantly modified in their physical characteristics. Consequently, further large-scale ocean tests were recommended.

Certain types of petroleum oils are prone to form water-in-oil emulsions (mousse) which adversely affect such cleanup procedures as mopping, skimming, and pumping (National Research Council 1985). The high water content (30-50% and higher) also inhibits combustion. Consequently a surface active agent to break water-in-oil emulsions was also tested as a part of this project. Brand M, a liquid demoussifier/demulsifier, was formulated by Environment Canada and contains a variety of polymeric agents in a hydrocarbon carrier.

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[1] General Technology Applications Inc., Manassas, VA

2.0 EXPERIMENTAL METHOD

2.1 Site

The site chosen was 44°15'N 61°50'W which lies about halfway between Halifax and Sable Island and is at least 60 km from the nearest coastline. Environment Canada judged that this site would be unlikely to suffer environmental damage as a result the activities planned. The water depth at this station is 172 m.

2.2 Materials tested

Two petroleum mixtures were used in the field trials: 1) Alberta Sweet Crude Oil (waxes and asphaltenes removed) and 2) a mixture (50:50) of the crude oil and bunker "A" (Bunker C cut with ca. 20% diesel fuel). The mixture was prepared by pumping the oils (crude oil first followed by Bunker "A") into a large (23,000-liter) cylindrical tank. Volumes were determined geometrically from dipstick level measurements. The crude oil (37 bbl) was stored in a second storage tank. Both tanks were subsequently secured to the aft deck of the CCGS Mary Hichens, the vessel used in the study.

2.3 Slick laying procedure

The plumbing system used to discharge the slicks from the aft deck of the CCGS Mary Hichens is shown in Figure 2.1. Oil was pumped from the bulk tanks into one of two 1000 L spill tanks. For each spill, 5 bbl (800 L) of oil was pumped into the spill tanks as determined by dipstick measurement.

For the demoussifier trial, the spill tanks were discharged via a 2.5" line equipped with flotation along its length and a paravane at the end to prevent flapping or snaking. The end of the discharge line was approximately 10 m ahead of the stern of the ship while oil was being discharged. When the contents of the spill tank were completely discharged, a 2-way valve was activated which allowed seawater to be pumped through the line, thus flushing out the residual oil and minimizing the amount of oil trailed behind the ship as it proceeded to the next spill site.

During the Elastol trials, the same plumbing arrangement was used to discharge the oil, but the end of the discharge hose was fixed near the starboard side of the ship, about 14 m ahead of the stern. This arrangement was used so that the oil could be treated as it passed under the applicators operated by personnel on the aft deck.

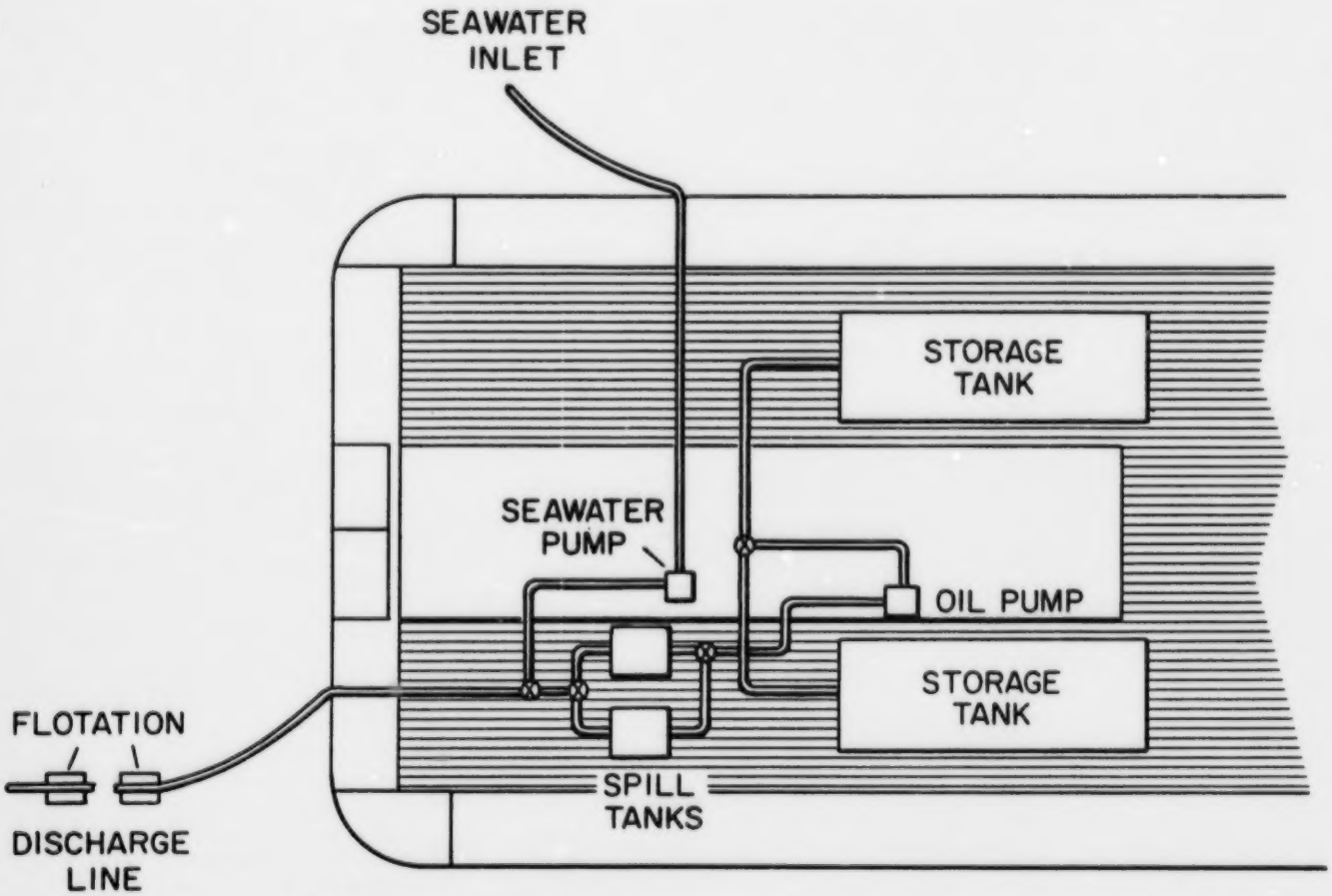


Figure 2.1. Plumbing for spill laying. The illustration shows the stern section of the CCGS Mary Hichens.

2.4 Slick treatment

One slick in both the demoussifier and Elastol trials was laid using oil treated with the appropriate agent immediately prior to discharge from the spill tank. The agent was added to the spill tank concurrently with the oil being pumped from the bulk tank to ensure that the agent would be well-mixed with the oil.

All other slicks were treated after laying (with the exception of the two control slicks) using specially modified applicators. Modified Campbell-Hausefield sandblasters (Power Blast Model AT1210) were used to dispense both the demoussifier and Elastol (Figure 2.2). The modified apparatus was designed by Environment Canada after evaluating several application systems on the basis of their: 1) uniform distribution characteristics, 2) portability and ruggedness, 3) safety, and 4) simplicity. Extensive testing of the distribution pattern of this applicator was undertaken by Bobra et al. (1987b). The applicators used for Elastol were fitted with vented hoppers to ensure continuous flow of the powdered agent. Similar modifications to the sandblasters were not required for application of the liquid demoussifier.

During the demoussifier trial, the slicks were treated from sampling boats (Rossboroughs). The boats approached the slick from up wind and sprayed it with the agent while traversing the slick in a zig-zag pattern until the downwind side of the slick was reached. This process was repeated until the entire dose of treating agent had been applied.

During the Elastol trial, heavy seas prevented the use of the sampling boats and the slicks were treated directly from the aft deck of the ship.

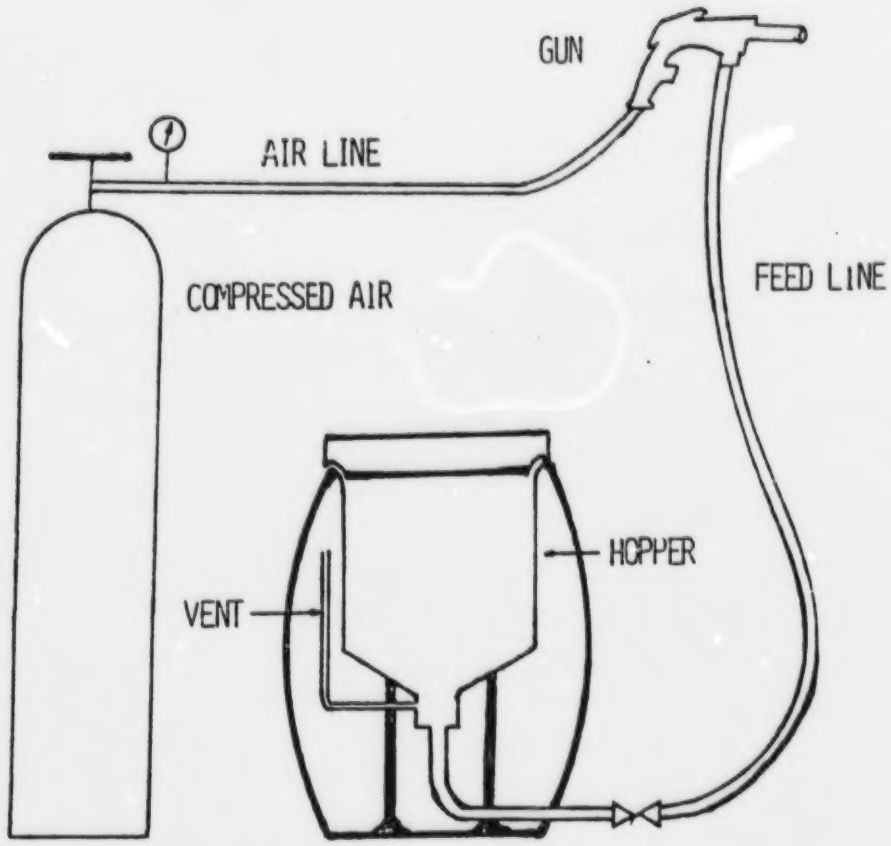


Figure 2.2. Applicator for treating agents.

2.5 Sample collection

Samples were obtained with the aid of plastic mesh baskets on the end of aluminum poles. The baskets are of a type commercially available for removing debris from swimming pools; the poles were fabricated by Environment Canada. Baskets were swept half-submerged through the slicks and when a sufficient amount of oil had been collected, the plastic mesh was snipped from the frame and allowed to fall into a 5-liter pail which was then labelled and sealed. Care was taken to obtain representative samples of the slicks, and samples were not taken from sheen areas or exclusively in thickly-covered areas. A log of events and samples is presented in Appendix A.

During the demoussifier trial, each slick was sampled by small boat approximately one and four hours after the application of the demoussifier. In the case of slick #1, a sample was obtained 24 hours after application. During the collection period, the samples were periodically returned to the CCGS Mary Hichens where they were analysed immediately for water content and viscosity.

During the Elastol trial, baskets on extension poles were used to collect the samples, usually from the port side of the ship. All other sampling procedures were the same as in the demoussifier trial.

In neither trial was it possible to collect longterm samples (22-49 hrs after treatment) as was originally planned, as heavy weather on the second day effectively dispersed the slicks.

2.6 Analytical procedures

Oil samples taken from the slicks were processed as soon as possible on board ship where the following measurements were made: water content (spectrophotometry), viscosity (Brookfield), and elasticity (die swell).

Elasticity

The die swell apparatus used was similar to that described by Bobra (1987a) but used a mechanical syringe pump rather than air pressure as the driving force. The assembly comprised a plastic syringe fitted with a 12 gauge needle with the end cut at 90°. The syringe was filled with oil and a steady flow of oil established by means of the mechanical pump. The swelling of the stream of oil as it emerged from the tip of the needle was photographed with a Polaroid camera connected to a Leitz microscope.

Weathering by GC/FID

Subsamples were taken from each sample for onshore analysis by gas chromatography (GC-FID) to determine the extent of weathering of the oil. The samples were dissolved in hexane and diluted to an appropriate concentration for injection into the gas chromatograph (Hewlett-Packard 5830A with flame ionization detection), and analysed under the following conditions, with peak areas measured by the HP5834/30a integrator :

Column:	15 m x 0.532 mm, 1.5 um DB-5 bonded phase fused silica column (Megabore, J&W Scientific)
Carrier gas:	Nitrogen, column flow 8 ml/min.
Injector temp:	250°C
Temperature program:	Inject sample at 40°C, hold for 5 min., heat at rate of 8°C/min. to 260°C, hold for 10 min.
Detector temp:	280°C
Detector flow:	Hydrogen 30 ml/min, air 240 ml/min, nitrogen makeup 22 ml/min.

3.0 RESULTS

3.1 Cruise plan/ship movements

Activities and movements during the experiment are illustrated in Figure 3.1. For additional information consult the chronological list of activities in Appendix A.

Upon reaching the study site, a Datawell surface-following accelerometer buoy (waverider) was deployed on a deep water mooring. This buoy transmitted wave height and frequency to a DIWAR receiver located on the bridge of the CCGS Mary Hichens. The DIWAR received signals from the buoy and converted the signal to a RS232 serial data string which was displayed in real time and logged on floppy disk on a portable computer.

An initial test of the slick laying technique and sample collection technique was carried out using a water-soluble dye. This was immediately followed by the laying of the first slick. Within 3 hours all five slicks (D1-D5 on Figure 3.1) in the demoussifier series had been laid, treated and sampled according to the schedules given in Table 3.1 and Appendix A. The one hour samples were taken by the sampling boats at positions which are essentially identical to those marked as the discharge positions.

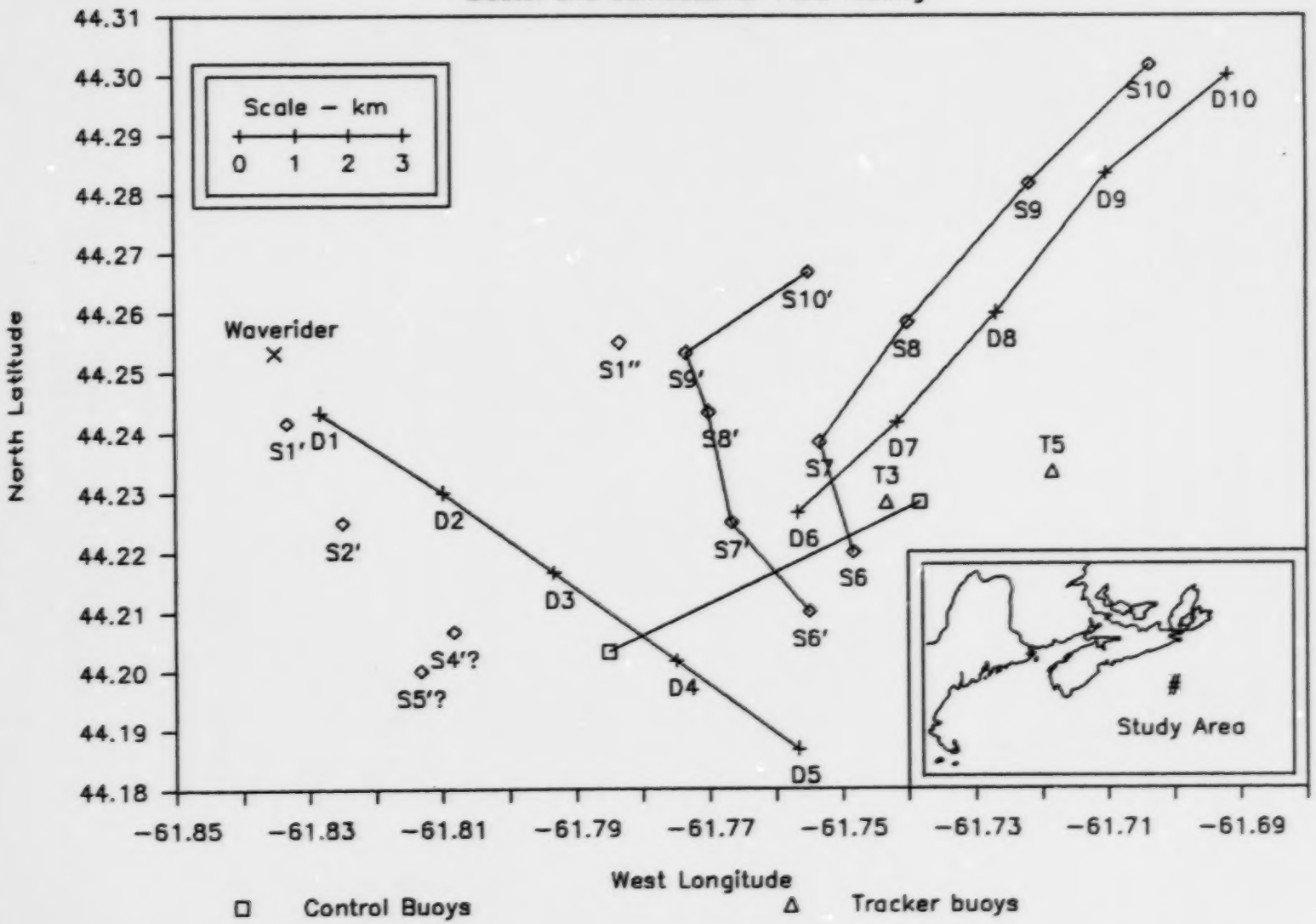
Table 3.1 Slick Specifications and Order

DEMULSIFIER (Day 1)	ELASTOL (Day 2)	Notes
Slick #1 (1000 ppm)	Slick #6 (3000 ppm)	Medium treatment
Slick #2 (250 ppm)	Slick #7 (1000 ppm)	Low treatment
Slick #3 (0 ppm)	Slick #8 (0 ppm)	Control
Slick #4 (4000 ppm)*	Slick #9 (9000 ppm)	High treatment
Slick #5 (1000 ppm)	Slick #10 (3000 ppm)	Medium pre-treatment

* delayed (6 hr) treatment

A second sampling round was initiated approximately four hours after the first slick had been treated, and samples were collected from each of

Figure 3.1 Site plan



NOTE: For detailed explanation please see text and Appendix A.

the slicks during the next two hours. The approximate position of the slicks at this time is indicated by the position of the ship (S1',S2' etc. on Figure 3.1, corresponding to the slick number). Slick sightings were southwest of the track where they were originally laid.

An attempt was made to find slicks #1-5 approximately 24 hours after the first slick was laid. In one area (S1'', Figure 3.1) oil was found that could have been the remnants of slick #1 (see section 3.5). A small slick was spotted at the position where the second slick was expected. Otherwise no surface oil was found that could be identified with the slicks laid the previous day.

Also after 24 hours, the Orion drifting buoys were sighted at the positions marked T3 and T5 on Figure 3.1. These buoys were released when slicks #3 and #5 were discharged. The buoys thus had moved to the northeast of the track while the slicks drifted to the southwest. A group of miscellaneous surface tracking buoys that were released between slick #3 and #4 were also found near where drifters from slicks #3 and #5 were recovered (indicated by two squares joined by a line).

Slicks #6 through #10 (D6-D10 on Figure 3.1) were laid and treated on September 10 in quick succession over a period of about 1.5 hours. The ship then proceeded to the site of slick #6 and the first sample was taken two hours after the time of treatment. As noted previously, samples were taken directly from the ship. Within the next hour the remaining four slicks were sampled (S6, S7 etc, Figure 3.1). Six hours after slick #6 was laid, it and slicks #7 and #8 were sampled. The slick positions at this time are indicated in Figure 3.1 (S6', S7' etc.). It was necessary to delay collection of samples from slicks #9 and #10 by one hour since increasingly high seas made it necessary to recover the waverider buoy. No further samples were taken due to the rough seas.

The pattern of slicks along the track (S6' to S10') for the second set of samples is not as regular as for the first sampling round and identification of some of the slicks may be incorrect. For example, S8' and

S9' may represent the same slick, while what was sampled as slick S10' appears to be far to the southwest of slick 10's original position.

3.2 Meteorological/oceanographic conditions

Meterological observations (wind speed and direction, temperature, sea state) were taken at regular intervals by the watch keeper. These data are summarized in Appendix E.

Processed wave height and frequency data from the waverider are presented in Figure 3.2 and Appendix C. Significant wave height and maximum heave records indicate that surface wave energy increased dramatically between the commencement of the trials on the morning of 9 September and when they ended on the evening of 10 September (Figure 3.2). The significant wave height was smaller by a factor of three (ca. 0.5 m) at the time of the demoussifier trials than during the Elastol trials (2.5 m).

A better estimate of the wave energy available for mixing can be made through analysis of the energy density spectra presented in Appendix C. Energy transfer from the waves to the slick most likely occurs through the action of breaking waves which are generated by the higher frequency, wind-driven waves. The spectra in Appendix C show a bimodal distribution of energy; the lower group of frequencies represent the long period swell and the higher frequencies are the wind driven waves which quite obviously grew in intensity as the trials progressed. It is the latter group which best represent that portion of the wave energy which would be effective in mixing the treating agents with the oil in the slicks. To extract a rough quantitative estimate of this energy, the energy density was integrated over a frequency range of 0.15 to 0.3 Hz to give a value proportional to the

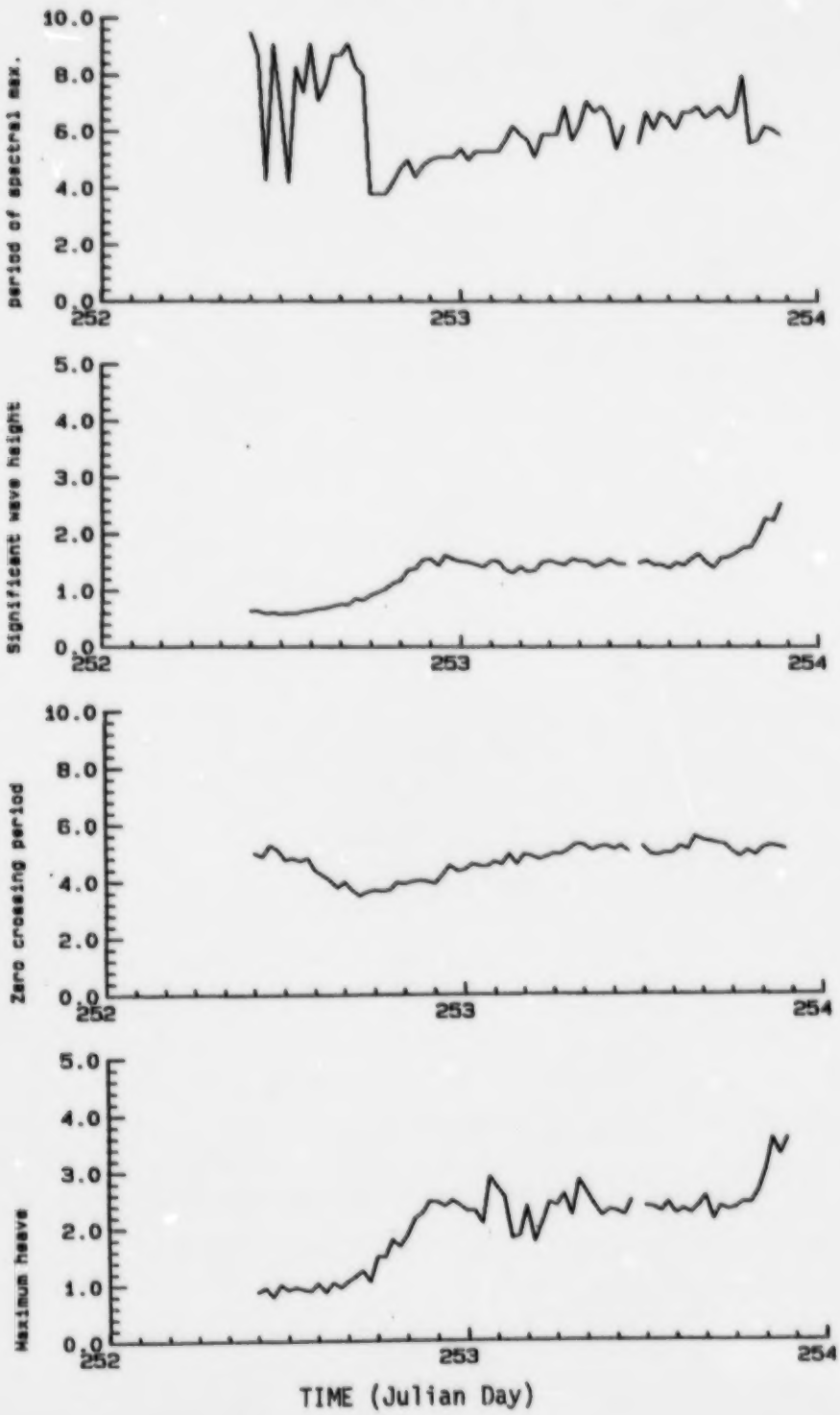


Figure 3.2. Processed waverider data.

square of the significant wave height. The energy available is given by:

$$E = \frac{pgH^2}{8} \qquad (1)$$

where **p** is the density, **g** the acceleration of gravity, and **H** the wave height. It is sufficient for the purpose of comparing wave energies at different times during our experiment to allow that the energy is proportional to the square of the wave height. The relative wave energy increased by a factor of seven over the period of the trials (Table 3.2).

Table 3.2 Relative wave energy

Day/Time		Relative wave energy
09/09/87	1400	1.0
	1800	2.2
	2200	7.7
10/09/87	0400	4.7
	0800	7.0
	1600	6.7

3.3 Physico/chemical measurements on demoussifier-treated slicks

The first five slicks were laid using the crude/bunker mixture and were treated with the following concentrations of Brand M demoussifier (Table 3.3):

Table 3.3. Demoussifier treatment concentrations

Slick #	Concentration of demoussifier	Comments
1	1000 ppm	Medium dose
2	250 ppm	Low dose
3	0 ppm	Control slick
4	4000 ppm	High dose (treatment delayed - 6hr)
5	1000 ppm	Medium dose (pre-treated)

Table 3.4 and Figures 3.3 and 3.4 show the results of the viscosity and water content measurements on samples, collected as noted one hour and five hours after treatment.

Table 3.4 Viscosity and water content of Slicks 1-5

Slick #	Concentration of demoussifier	Viscosity (cp)		Water content (%)		Occurrence of mousse	
		1hr	5hr	1hr	5hr	1hr	5hr
3	0 ppm	6350	320000	88	95	++	++
2	250 ppm	2700	62250	54	93	-	-
1	1000 ppm	10000	84250	84	90	-	-
4	4000 ppm	2200	105000	72	90	+	+[2]
			22600		78		-[3]
5	1000 ppm[1]	970	38500	32	80	-	-

1. pretreated; 2. at 6 hours - before treatment; 3. after treatment

The demoussifier was very effective in preventing large viscosity increases in the treated slicks. The samples taken from the slicks one hour after being treated showed relatively uniform viscosities in the range of 2000 to 10000 centipoise (cp) with the pretreated slick having the lowest viscosity. The samples taken approximately five hours after treatment all had higher viscosities. The control slick exhibited the highest viscosity and a heavy mousse was prevalent. The slicks treated with the low and medium doses of demoussifier, however, had dramatically lower viscosities than the untreated slick and no evidence of mousse was noted in either case.

The untreated slick (#4) had a high viscosity and developed patches of mousse at the 5-hour time interval. When this slick was treated with demoussifier, the mousse began to break up and the viscosity measured one hour after treatment had fallen to 20% of the pretreatment level. The mousse broke up almost immediately in areas that were sprayed directly. The emulsion broke up over a period of minutes in other areas of the slick, where presumably the demoussifier flowed in from sprayed areas.

Water content did not appear to be a good indicator of mousse formation; all slicks accumulated a large amount of water (Figure 3.4).

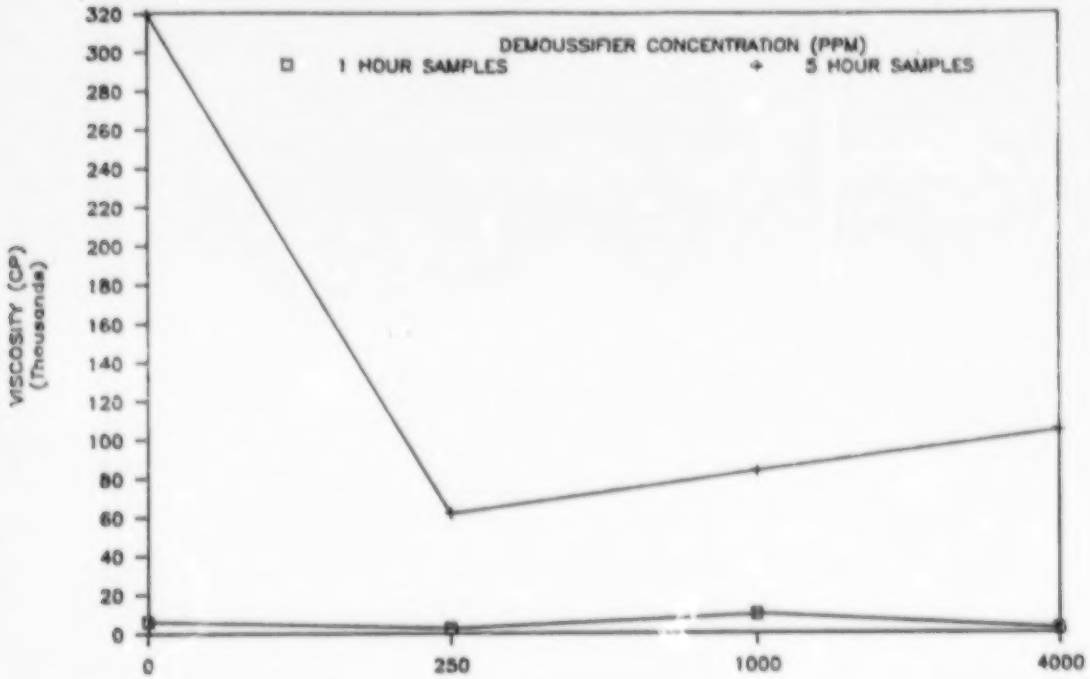


Figure 3.3. Viscosity of Slicks 1-5.

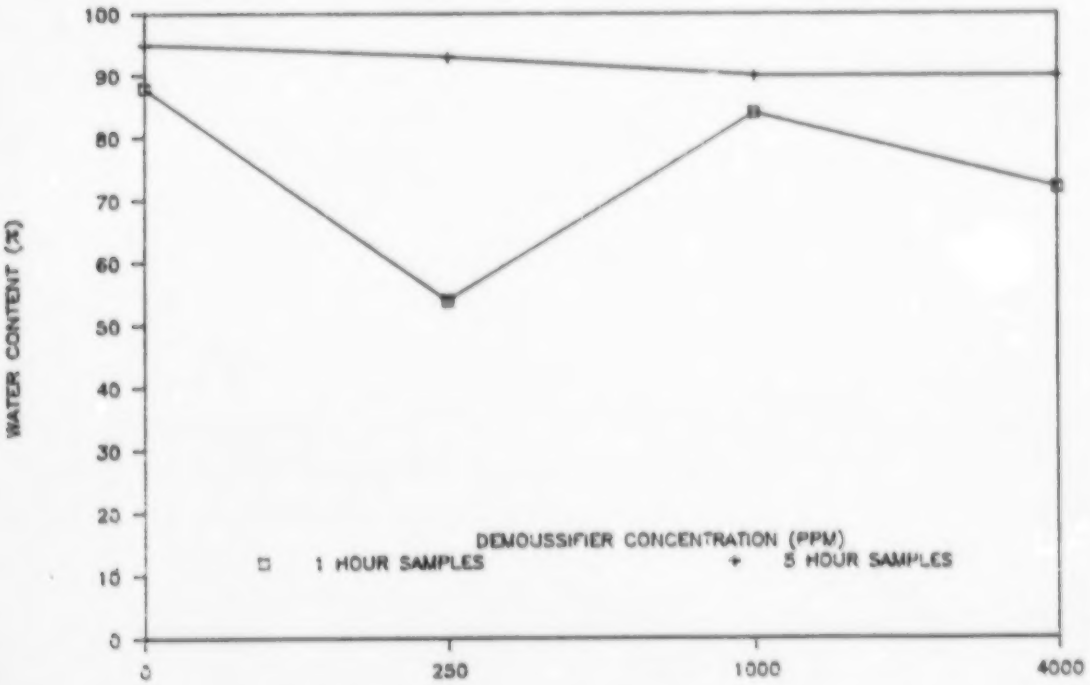


Figure 3.4. Water content of Slicks 1-5.

Although some formed mousse (as evidenced by the reddish colouration, high viscosity and stability), others did not but still had high water content. Existing models do not predict the high water contents observed during this field trial.

To summarize, the slicks treated with demoussifier at the time of laying and the pretreated slick had markedly lower viscosities and showed no tendency to form mousse while the untreated slicks became heavily moussified. Demoussifier applied to a slick that had already developed mousse had the effect of rapidly breaking up the emulsion.

3.4 Physico/chemical measurements on Elastol-treated slicks

Treatment conditions for the five crude oil slicks laid during the Elastol trials are presented in Table 3.5.

Table 3.5 Elastol treatment concentrations

Slick #	Concentration of demoussifier	Comments
6	3000 ppm	Medium dose
7	1000 ppm	Low dose
8	0 ppm	Control slick
9	9000 ppm	High dose
10	3000 ppm	Medium dose (pre-treated)

Oil samples were collected from the slicks approximately one hour and five hours after treatment. Viscosity and elasticity (die swell) measurements on these samples are presented in Figures 3.5 and 3.6 and Table 3.6.

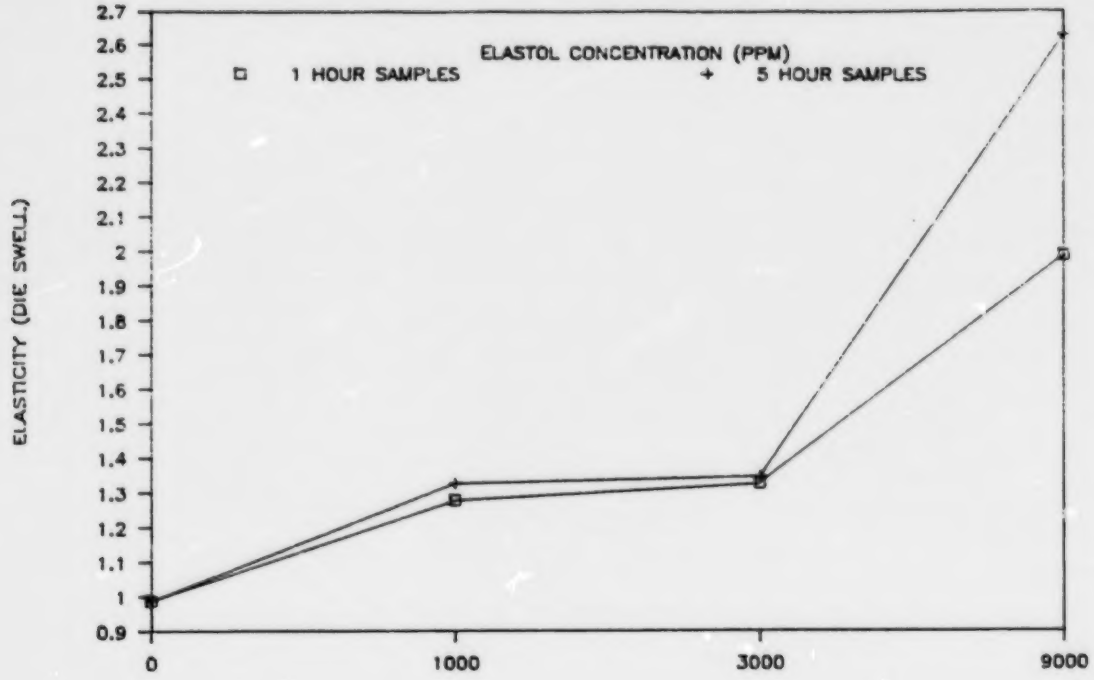


Figure 3.5. Viscosity of Slicks 6-10. Elastol application.

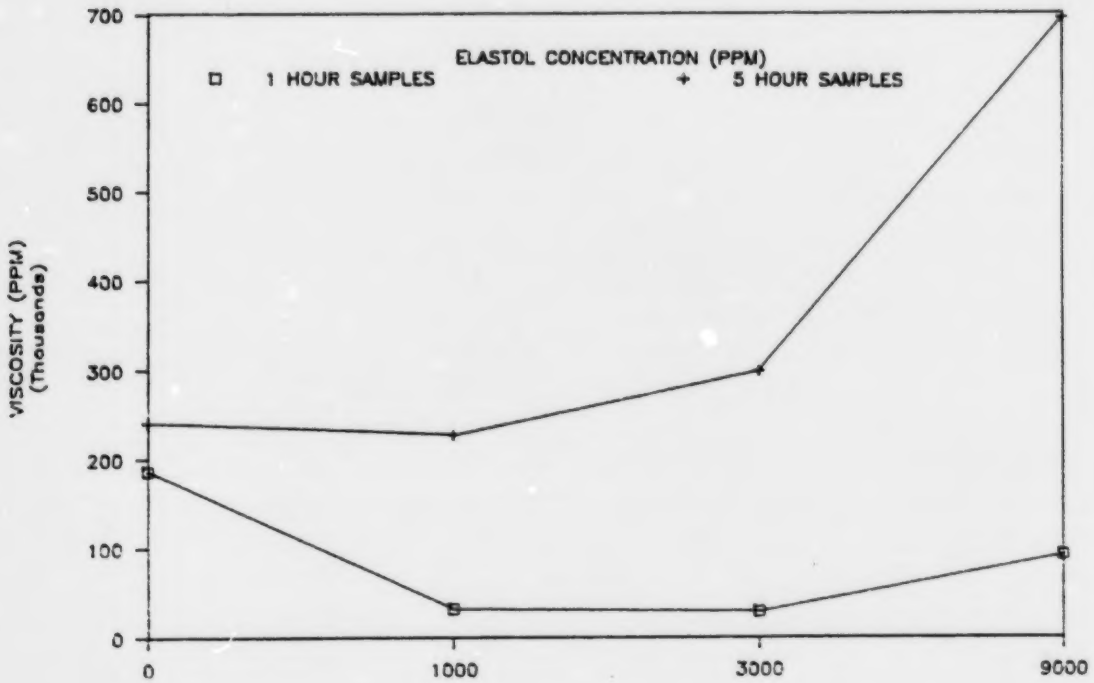


Figure 3.6. Elasticity of Slicks 6-10. Elastol application.

Table 3.6 Viscosity & elasticity of slicks 6-10

Slick #	Concentration of Elastol	Viscosity (cp)		Elasticity (die swell)		"Observed" elasticity	
		1hr	5hr	1hr	5hr	1hr	5hr
8	0 ppm	187000	242000	0.99	0.99	none	none
7	1000 ppm	32250	228000	1.28	1.33	low	med
6	3000 ppm	29300	300000	1.33	1.35	med	high
9	9000 ppm	93000	696000	1.99	2.63	high	super
10	3000 ppm*	170500	156000	1.35	1.57	med	high

* pre-treated

These measurements as well as observations of the physical properties of the slicks taken at time of sampling, indicate that Elastol was effective in increasing the viscoelasticity of the oil. Viscosity of the Elastol-treated slicks increased 7.5-10 fold over a five hour period (Table 3.6; Figure 3.5). The viscosity of the untreated slick, though high at the one-hour interval, increased by only 20% over five hours, presumably as a result of water uptake and/or emulsion formation (Bobra 1987a). The growth of viscosity in the treated slicks, on the other hand, shows a positive correlation with the concentration of Elastol applied (Figure 3.5).

The effect of the treatment on the viscoelasticity of the oil is shown more clearly by the die swell measurements. Samples taken from the control slick at one and five hours had die-swell ratios of zero (no elasticity) while those from the slicks treated with low and medium concentrations of Elastol had ratios of about 1.35 (Table 3.6). These ratios are as high or higher than those obtained by Bobra (1987a) from laboratory tank tests in which similar concentrations of Elastol were used. It is also interesting to note that the maximum die swell ratios were reached before the one-hour sampling and remained essentially unchanged at five hours.

The slick treated with the highest dose (9000 ppm) of Elastol showed the highest elasticity, with the die swell ratio increasing from 2 to 2.6

over the five hours between samples. Although all samples taken from the treated slicks were obviously elastic, the five-hour sample from the slick treated with 9000 ppm Elastol appeared to be almost semi-solid (super-elastic) (Table 3.6). This slick showed a higher elasticity than any of the samples from the laboratory tests of Elastol (Bobra 1987a), presumably as a result of the high mixing energy prevalent at the time of the field trials.

In summary, Elastol worked as well as or better than expected under natural oceanic conditions. High elasticities were observed at all treatment concentrations.

3.5 Weathering of treated slicks

The amount of weathering of the slicks was estimated by integrating the area under the peaks from C7 to C14 in GC chromatograms of slick samples, and normalizing them to the same quantity determined for the original oils. GC-FID data for the samples are summarized in Table 3.7 (chromatograms for each sample can be found in Appendix B). There was a progressive loss of light hydrocarbons over the 4 to 6 hour experimental period in all cases. The effect was less severe for the emulsifying mixture, as would be expected from its content of relatively heavy bunker A.

The GC chromatogram for the 24-hour sample from Slick 1 of the demoussifier trial (Appendix B) shows that this sample is the most weathered of any that was collected, which might be expected as a result of a long exposure time. However, the large unresolved envelope and the anomolously high viscosity (592,000 cp) may indicate that oil from another source, perhaps from a passing ship, may be a component of the sample.

Table 3.7 Weathering of Slicks in Field Test as determined by GC/FID.

Treatment Conc (ppm)	Slick	C7 - C14 (% of total area) Sample Initial	2nd	3rd	Normalized Sample Initial	2nd	3rd
Brand M Demoussifier							
-	mix	35.7	-	-	100.0	-	-
0	3	19.2	3.6	-	53.8	10.1	-
250	2	20.3	9.5	-	56.9	26.6	-
1000	1	14.4	9.2	0.6*	40.3	25.8	1.7
1000	5p	29.1	15.0	-	81.5	42.0	-
4000	4	26.5	13.1	16.0	74.2	36.7	44.8
ELASTOL							
-	crude	58.7	-	-	100.0	-	-
0	8	10.6	8.7	-	18.1	14.8	-
1000	7	19.5	4.0	-	33.2	6.8	-
3000	6	18.4	11.6	-	31.3	19.8	-
3000	10p	20.1	6.3	-	34.2	10.7	-
9000	9	17.2	9.3	-	29.3	15.8	-

* Sampled 10 September, Day 2

3.6 Remote sensing

Overflights by Falcon Fan-Jet aircraft operated by the Canada Centre for Remote Sensing collected data on slick positions and area by IR/UV scanning. Unfortunately, bad weather conditions severely curtailed the planned schedule of flights. Data on slicks gathered from the aircraft on 9 September (demoussifier trials) was not in a form in which it could be readily incorporated in this report.

3.7 Physical behaviour of slicks

As previously discussed, the experiment was characterized by high wave energy which tended to disperse the test slicks only a relatively short time after they were laid. The following observations thus are relevant only to

the physical behaviour of the slicks over a four to six hour period after application of the treatment agents:

- Formation of water-in-oil emulsions appeared to be inhibited in the treated slicks compared to the control slick and the slick treated at the four-hour time period;

- direct application of the demoussifier to patches of mousse in the untreated slicks broke up the emulsion immediately (10-15 seconds);

- mousse in areas of the slick not directly sprayed appeared to break up when the agent migrated from sprayed areas (ca. 10 minutes);

- Elastol had the desired effect of increasing the viscoelasticity of the oil (as measured in the onboard ship) but due to the high mixing energy present at the surface, did not result in a particularly cohesive slick;

- The application method did not seem to be particularly critical, i.e. if the agents were applied in a non-uniform manner, they appeared to migrate to all portions of the slick through the mixing action of the waves.

4.0 CONCLUSIONS

The period over which the trials were run was characterized by high wave energy and this tended to disperse the test slicks only a relatively short time (ca. 12 hours) after they were laid. Thus the long-term effects of the treating agents cannot be assessed from the data collected during this study. However, the following conclusions can be made from this study:

- Brand M demoussifier worked well over a 4-6 hour period. The formation of water-in-oil emulsions was inhibited in the slicks treated with demoussifier.

- The direct application of the demulsifier to patches of mousse in the untreated slicks had the immediate effect of breaking up the emulsion (10-15 seconds);

- Mousse in areas of the slick not directly sprayed appeared to break up when the agent migrated from sprayed areas (ca. 10 minutes).

- Water content did not appear to be a good indicator of mousse formation; all slicks accumulated a large quantity of water whether mousse was present or not.

- Elastol increased the viscoelasticity of the oil in the treated slicks to a greater extent than expected from previous laboratory studies.

- The manner in which either of the agents was applied did not seem to particularly critical, i.e. if the agents were applied in a non-uniform manner, they appeared to migrate to all portions of the slick through the mixing action of the waves.

5.0 REFERENCES

Bobra, M.A., P.I. Kawamura, M. Fingas and D. Velicogna, "Laboratory and tank test evaluation of Elastol", Proceedings of the tenth Arctic Marine Oilspill Program Technical Seminar, Edmonton, Alta., June 9-11, 1987, pp. 223-241, (1987a)

Bobra, M.A., P.I. Kawamura, M. Fingas and D. Velicogna, "Mesoscale application and testing of an oil spill demulsifying agent and Elastol", Preprint prepared for U.S. Minerals Management Service, September, 1987, (1987b)

National Research Council, Oil In the Sea: Inputs, Fates and Effects, National Academy Press, Washington, D.C., pp. 279-281, 1985

Waters, P. and A.F. Haderman, "The efficiency of elastomers in oil spill cleanup", 1987 Oil Spill Conference, Baltimore, MD, pp. 231-233, (1987)

6.0 ACKNOWLEDGMENTS

This field study was brought to a successful conclusion in spite less than ideal environmental conditions through the coordinated efforts of personnel from a variety of organizations. They were:

Environment Canada:	M. Fingas R. Percy
Consultchem:	M. Bobra
Materials Management Service:	E. Tennyson L. Hannon
Canadian Coast Guard:	R. Stright R. Carpenter Captain & crew of the CCGS Mary Hichens
General Technology Applications:	E. Tedeschi
Esso Resources Canada	R. Goodman
Canada Centre for Remote Sensing	W. McColl

APPENDIX A - FIELD NOTES

Tuesday, 08 Sept 1987

0800 ADT CCGS Mary Hichens secured at Mulgrave dock; loading Equipment for field trial.

2000 All clear Mulgrave Dock.

Wednesday, 09 Sept 1987

0640 Deployed waverider buoy;
44°15.2'N 61°50.1'W; l/c 13768.8 29350.4;
Depth 152 m.

0700 Sample boats 1 & 2 in water; conduct trial exercise with dye.

0732 Sample boats onboard.

0850 Sample boats away.

0909 Discharging slick #1;
44°14.6'N 61°49.7'W; l/c 13765.9 29345.9;
tracking buoy #1 in water.

0924 Discharging slick #2;
44°13.8'N 61°48.6'W; l/c 13761.3 29337.0

0939 Discharging slick #3;
44°13.0'N 61°47.6'W; l/c 13756.9 29328.0;
tracking buoy #3 in water.

0955 Dropped six control buoys;
44°12.2'N 61'47.1'.

1024 Slick #2 sampled; bt. #2 same pos'n. as 0924 ADT.

1105 Slick #1 sampled; bt. #1 same pos'n. as 0909 ADT.

1125 Slick #3 sampled; bt. #1 same pos'n. as 0939 ADT.

1126 Discharging slick #4;
44°12.1'N 61°46.5'W; l/c 13752.2 29319.1;
slick not treated.

1140 Slick #4 sampled; bts. #1&2 same pos'n. as 1126 ADT.

1141 Discharging pretreated slick #5;
44°11.2'N 61°45.4'W; 1/c 13747.8 29310.5;
tracking buoy #4 in water.

1155 Slick #5 sampled; bt. #1 same pos'n. as 1141 ADT.

1217 Sample Boats on board.

1408 Sample Boats away; slick #1 pos'n.

1420 Slicks #1 and #2 sampled;
slick 1, bt. #1: 44°14.2'N 61°50.0'W; 1/c 13762 29345;
slick 2, bt. #2: 44°13.5'N 61°49.5'W; 1/c 13757 29341.

1425 Boat #2 delivers slick #2 sample.

1435 Boat #1 delivers slick #1 sample.

1500 Slick #3 sampled; bt. #1: pos'n?

1508 Boats & ship to slick #3.

1522 Boats & ship to slick #4.

1531 Slick #4 sampled then treated;
44°12.2'N 61°48.2'W; 1/c 13750 29332.

1606 Slick #4 sampled - post treatment; same pos'n as 1531 ADT.

1612 Boats & ship to slick #5.

1615 Slick #5 sampled;
44°12.0'N 61°48.8'W; 1/c 13748 29334.

1648 Boats on board and samples delivered.

Thursday, 10 September 1987

0915 Sample slick #1 from Mary Hichens;
44°15.3'N 61°47.0'W

1047 Alongside tracker buoy #3;
44°13.7'N 61°44.6'W; no slick.

1050 Sighted 3 control buoys;
44°13.7'N 61°44.3'W; no slick.

1101 Alongside tracker buoy #4;
44°14.0'N 61°43.1'W; no slick.

1248 Discharging slick #6;
44°13.5'N 61°45.4'W; l/c 13758, 29309.

1249 Tracker buoy #4 away.

1253 Completed discharge, slick #6;
l/c 13759, 29307.

1306 Discharging slick #7;
44°14.5'N 61°44.5'W; l/c 13764, 29303.

1311 Completed discharge, slick #7;
l/c 13765, 29301.

1323 Discharging slick #8;
44°15.6'N 61°43.6'W; l/c 13771, 29297.

1325 Tracker buoy #5 away;
l/c 13772, 29296.

1327 Completed discharge, slick #8.

1348 Discharging slick #9;
44°17.0'N 61°42.6'W; l/c 13779, 29290.

1359 Completed discharge, slick #9;
l/c 13780, 29289.

1414 Discharging slick #10;
44°18.0'N 61°41.5'W; l/c 13785, 29283.

1416 Tracker buoy away.

1500 Slick #6 sampled from Mary Hichens;
44°13.2'N 61°44.9'W; l/c 13756, 29304.

1527 Slick #7 sampled from Mary Hichens;
44°14.3'N 61°45.2'W; l/c 13763, 29308.

1537 Slick #8 sampled from Mary Hichens;
44°15.5'N 61°44.4'W; l/c 13770, 29304.

1548 Slick #9 sampled from Mary Hichens;
44°16.9'N 61°43.3'W; l/c 13778, 29294.

1603 Slick #10 sampled from Mary Hichens;
44°18.1'N 61°42.2'W; l/c 13785, 29287.

1715 Slick #6 sampled from Mary Hichens;
44°12.6'N 61°45.3'W; 1/c 13753, 29313.

1800 Slick #7 sampled from Mary Hichens;
44°13.5'N 61°46.6'W; 1/c 13758, 29319.

1815 Slick #8 sampled from Mary Hichens;
44°14.6'N 61°46.2'W.

1840 Recovered waverider buoy.

1851 Recovered subsurface buoy; abandoned mooring due to heavy weather.

1915 Slick #9 sampled from Mary Hichens;
44°15.2'N 61°46.4'W.

1926 Slick #10 sampled from Mary Hichens;
44°16.0'N 61°45.3'W.

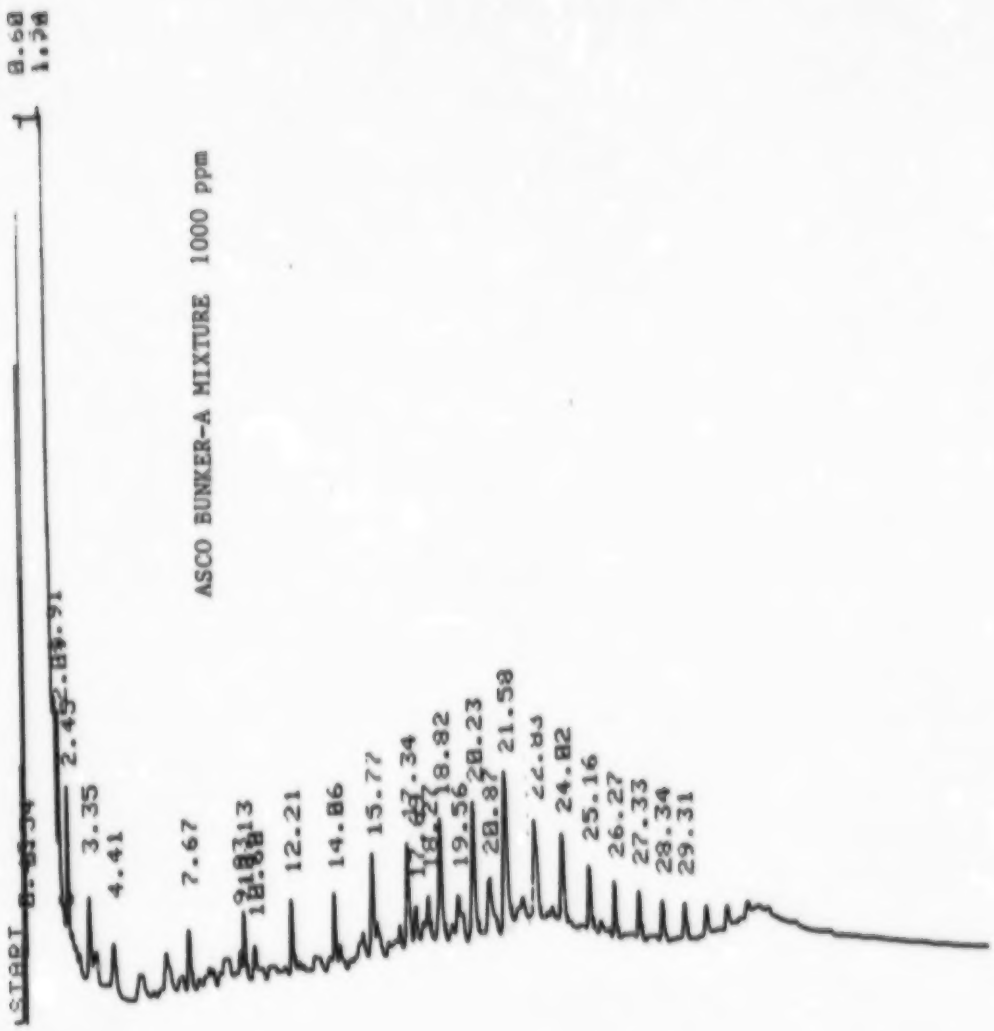
1935 Proceeding to Mulgrave due to heavy sea.

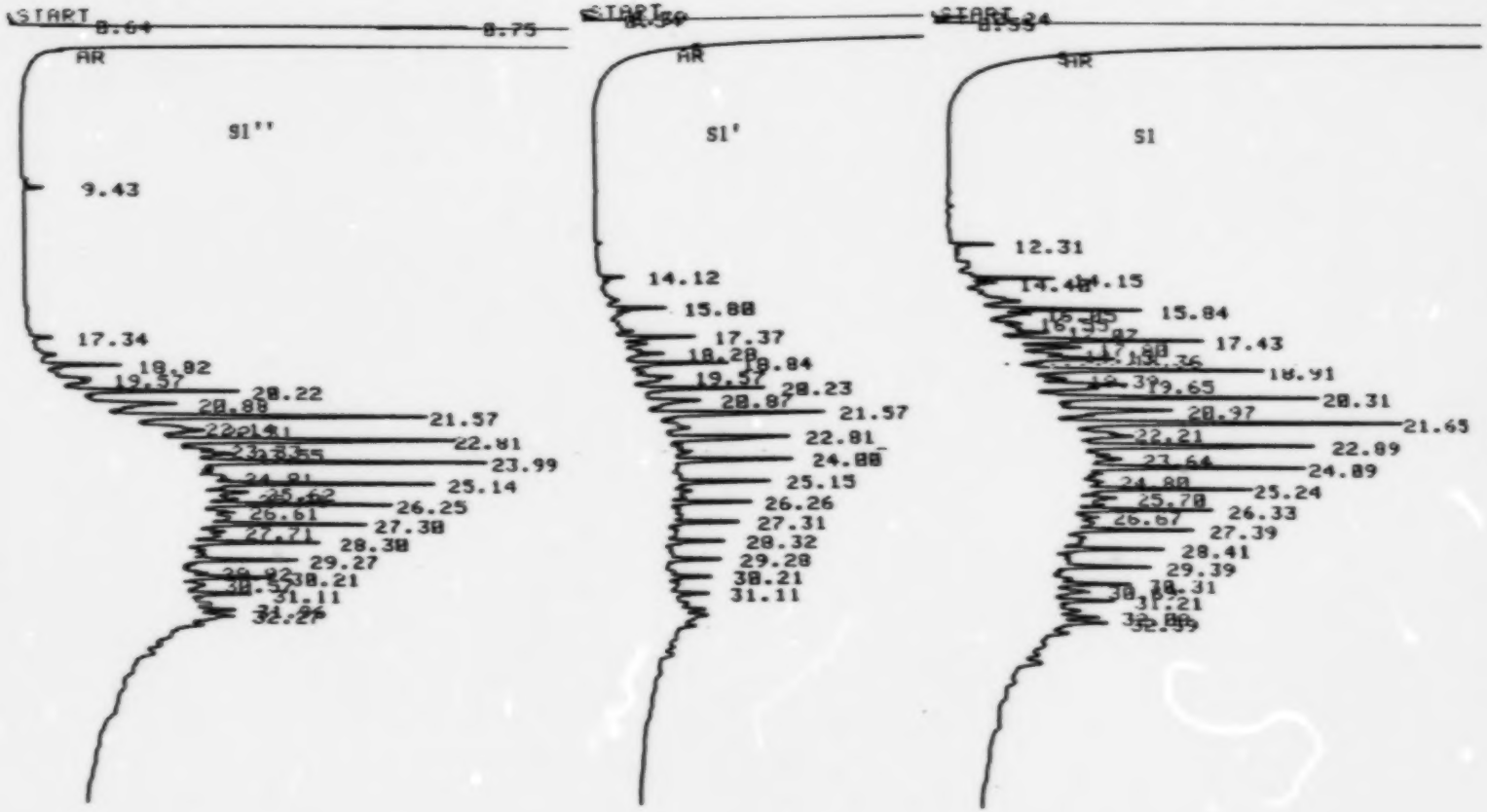
Friday, 11 September 1987

0646 Secured alongside Mulgrave dock.

APPENDIX B - GC CHROMATOGRAMS OF SLICK SAMPLES

DEMULSIFIER TRIAL

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23.99
25.14
26.25
26.61
27.38
28.38
29.27
38.21
31.11
S1'
14.12
15.88
17.37
18.84
19.57
20.23
20.87
21.57
22.81
24.88
25.15
26.26
27.31
28.32
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38.21
31.11
S1
12.31
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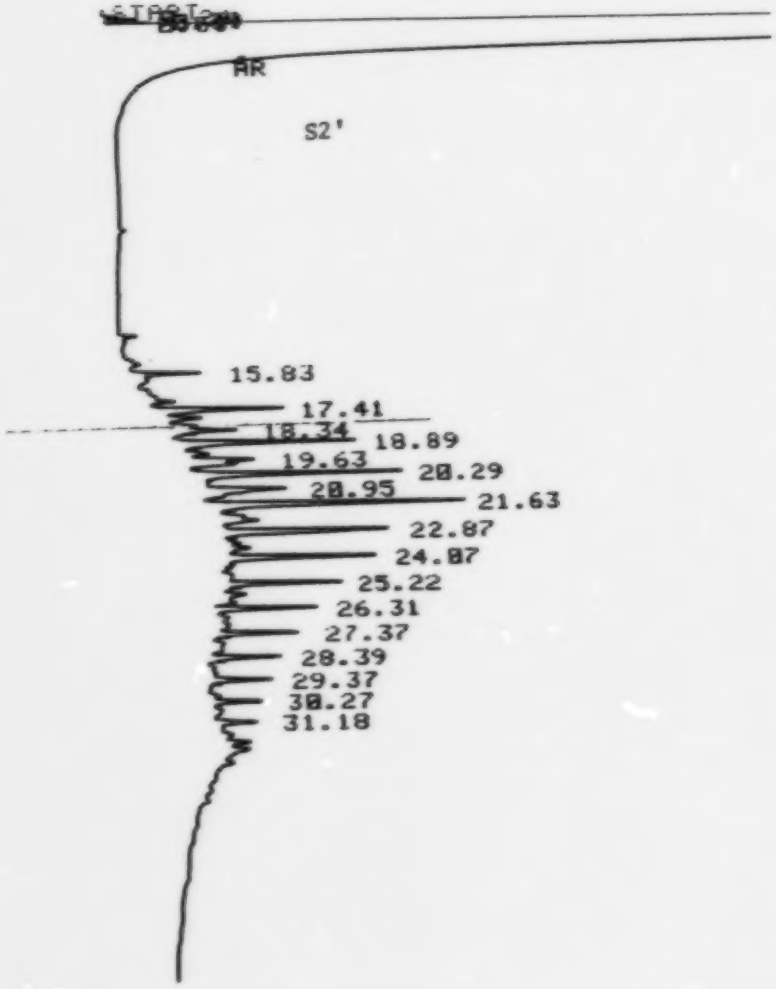
29.39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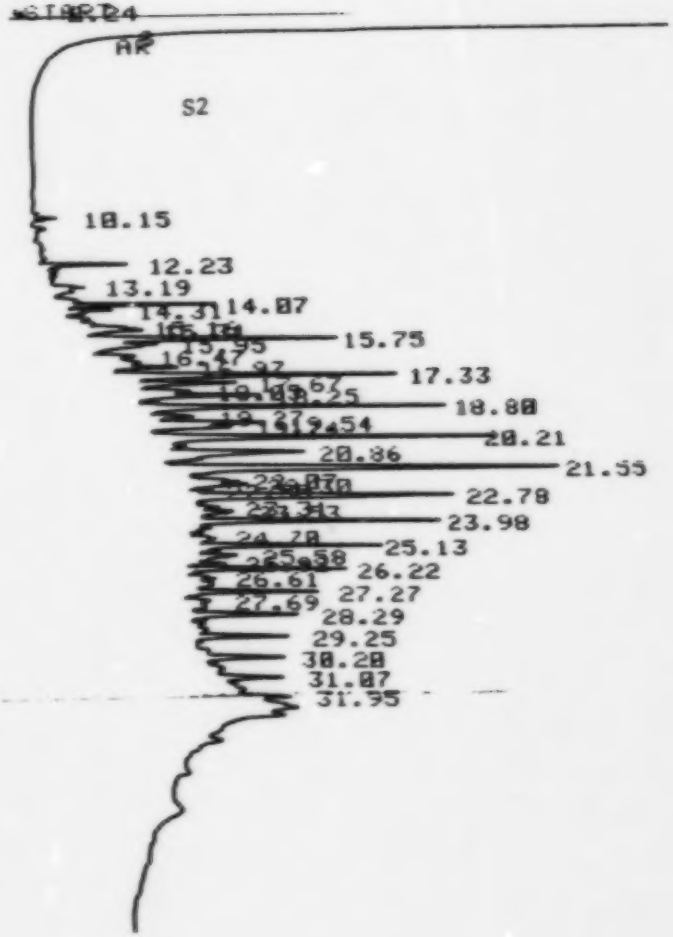
29.37
30.27
31.18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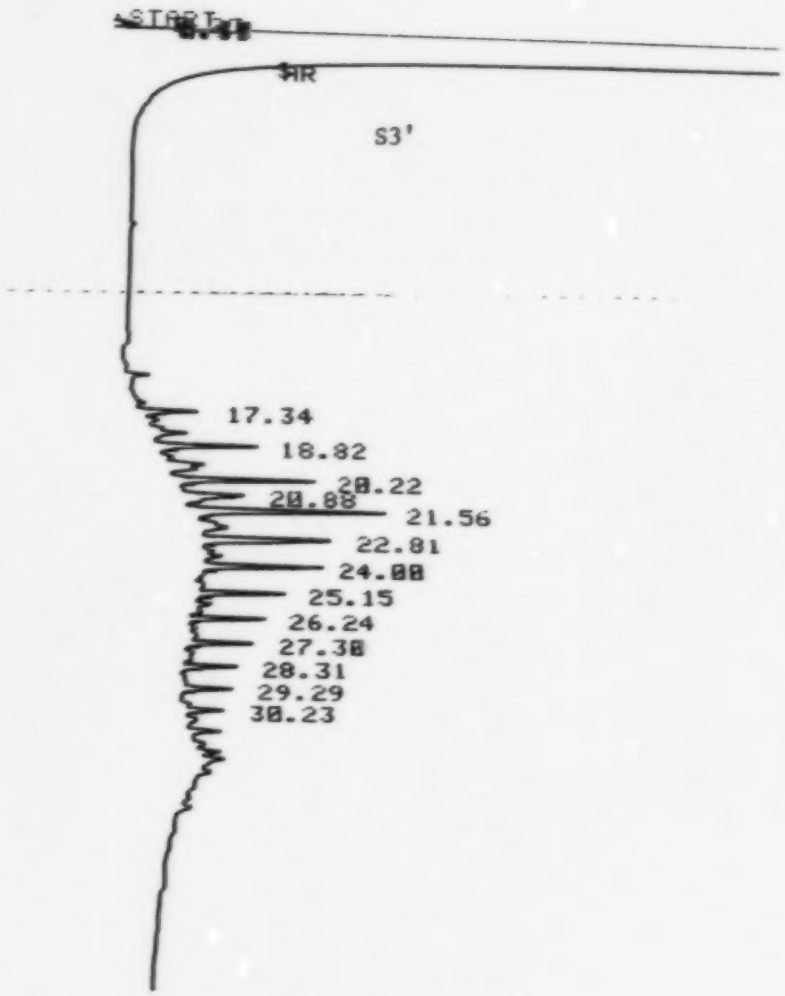
31.07
31.95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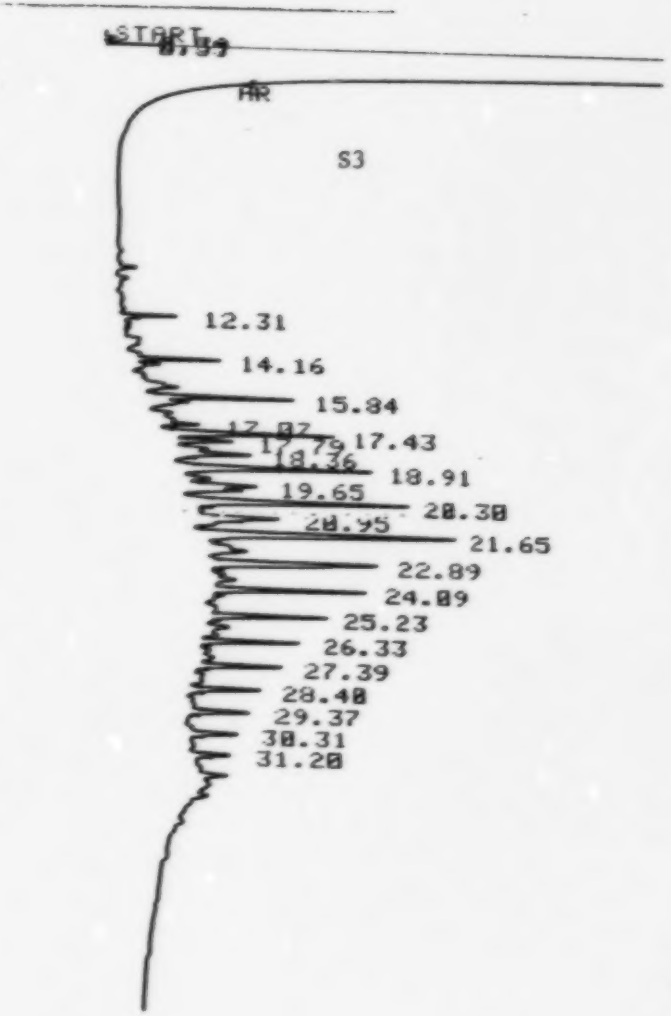
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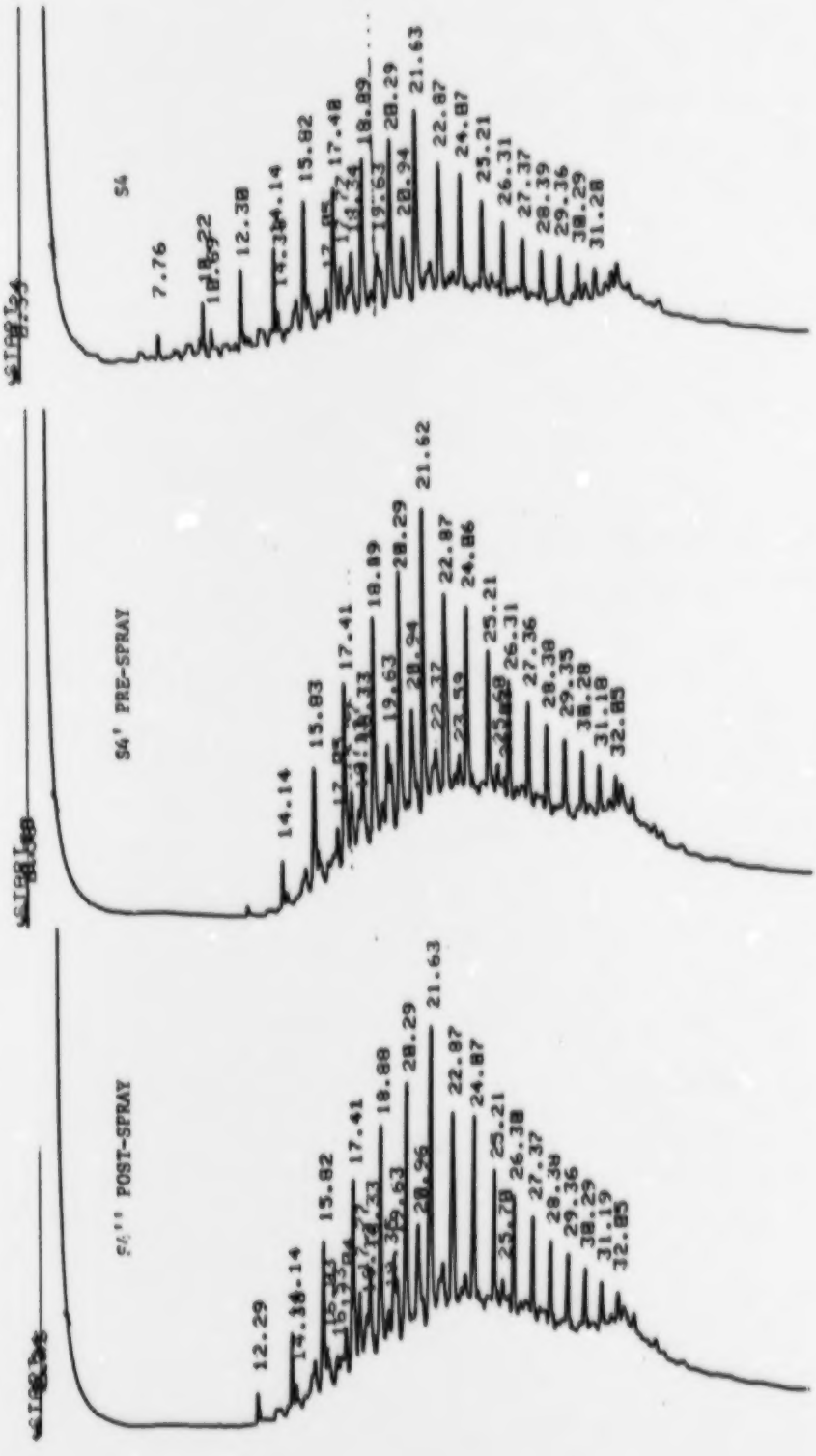
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21.63
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26.31
27.37
28.39
29.36
30.29
31.28
54' PRE-SPRAY
14.14
15.83
17.41
18.89
21.62
22.87
24.86
25.21
26.31
27.36
28.38
29.35
31.18
32.85
54'' POST-SPRAY
12.29
15.82
17.41
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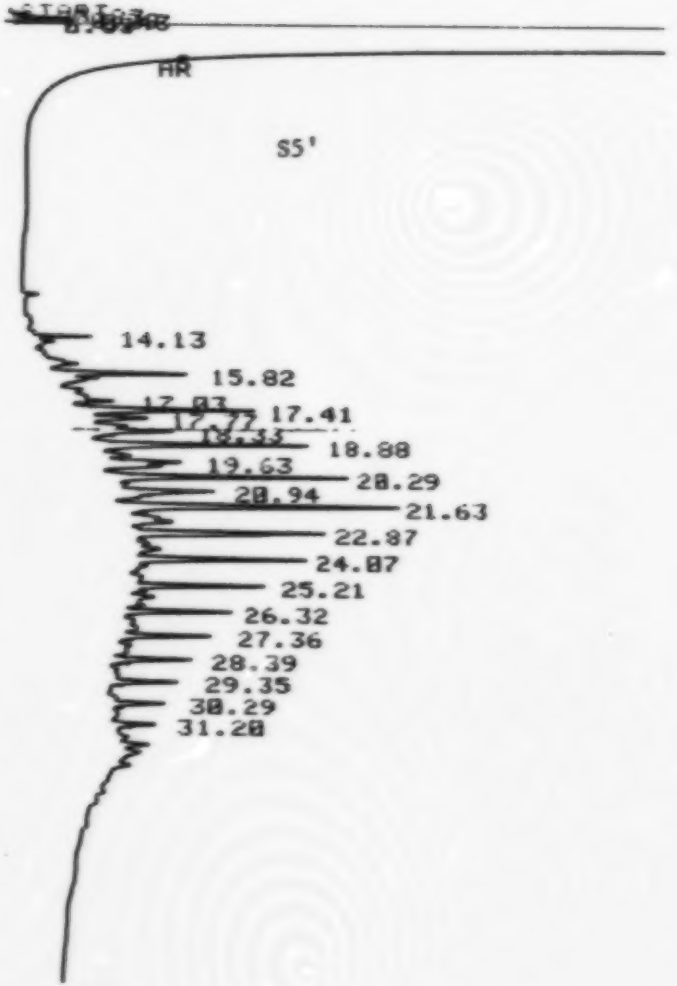
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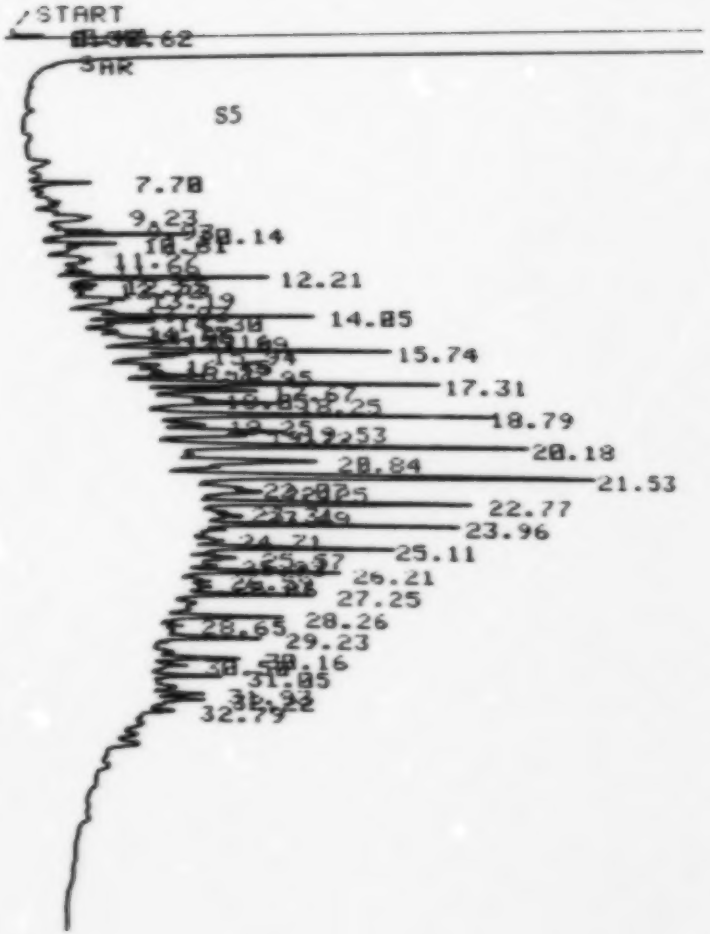
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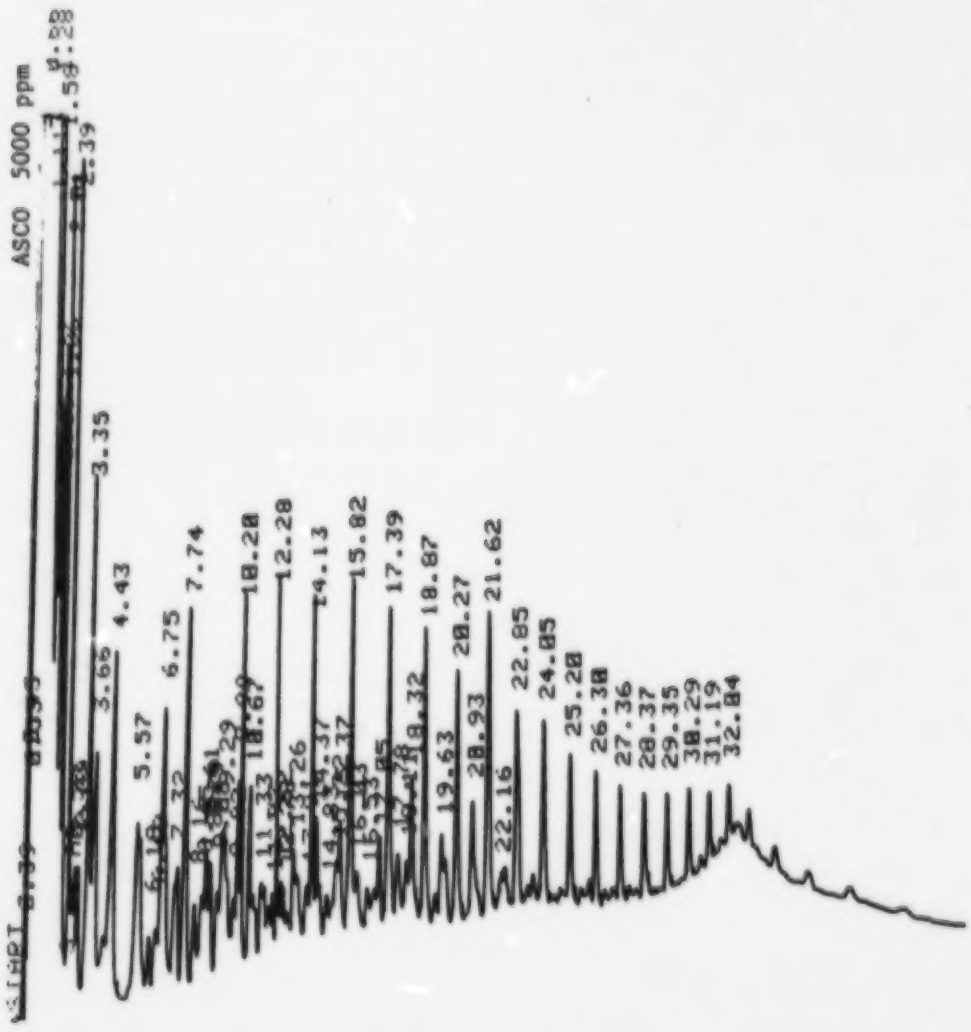
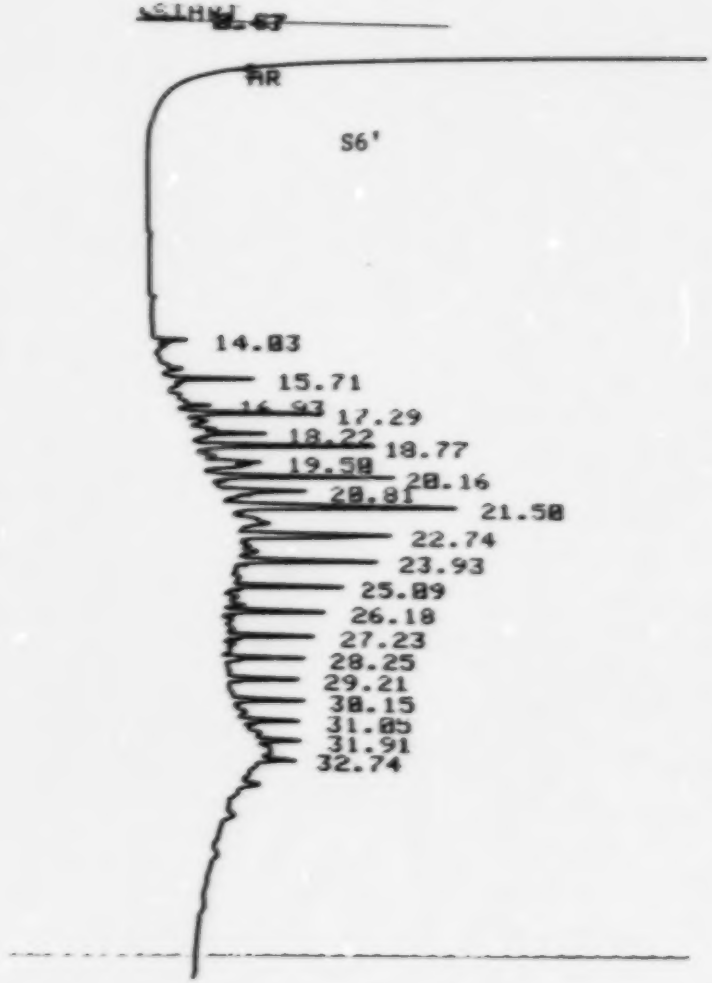
Elastol trial

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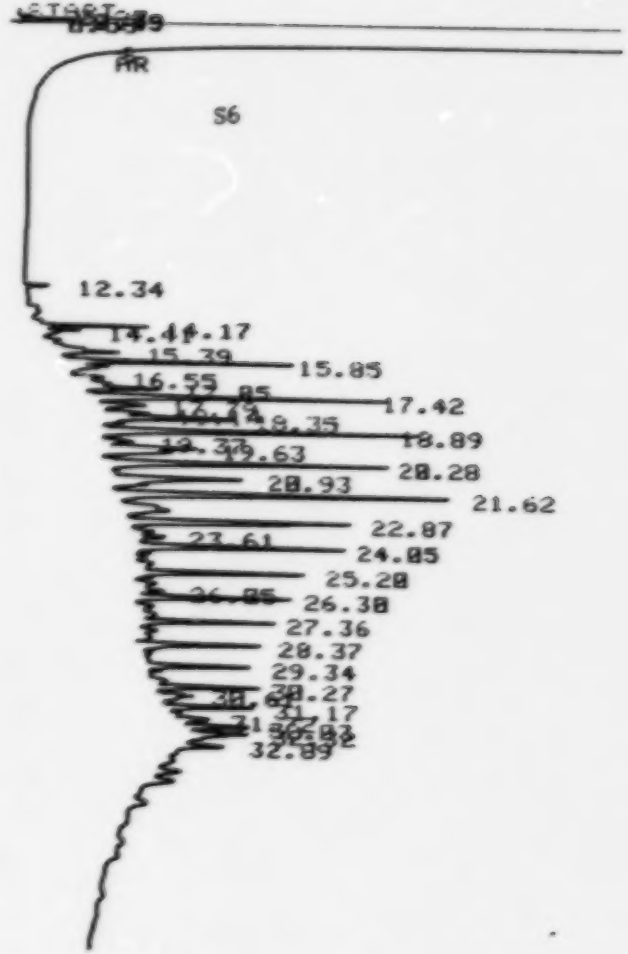
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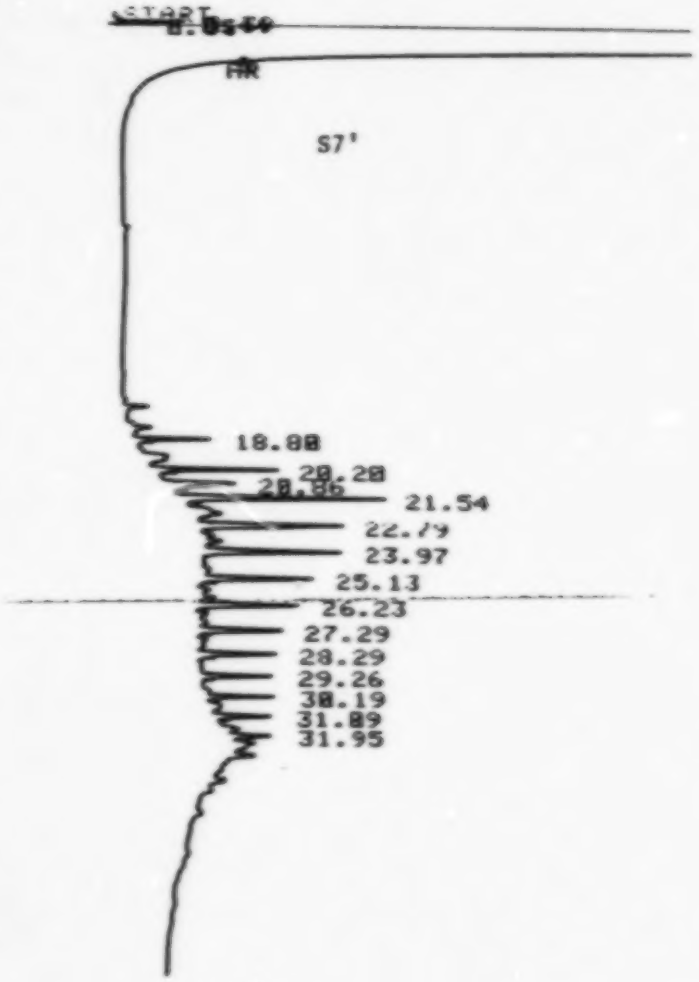
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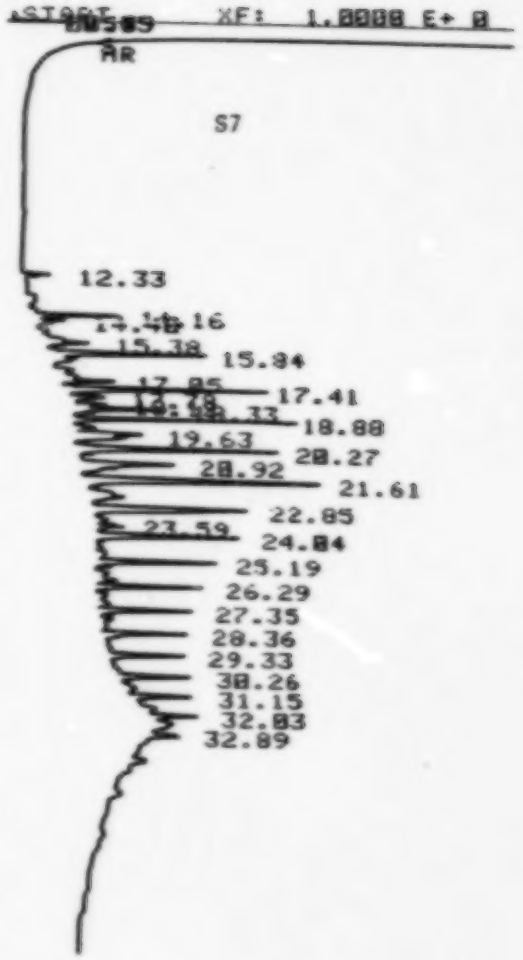
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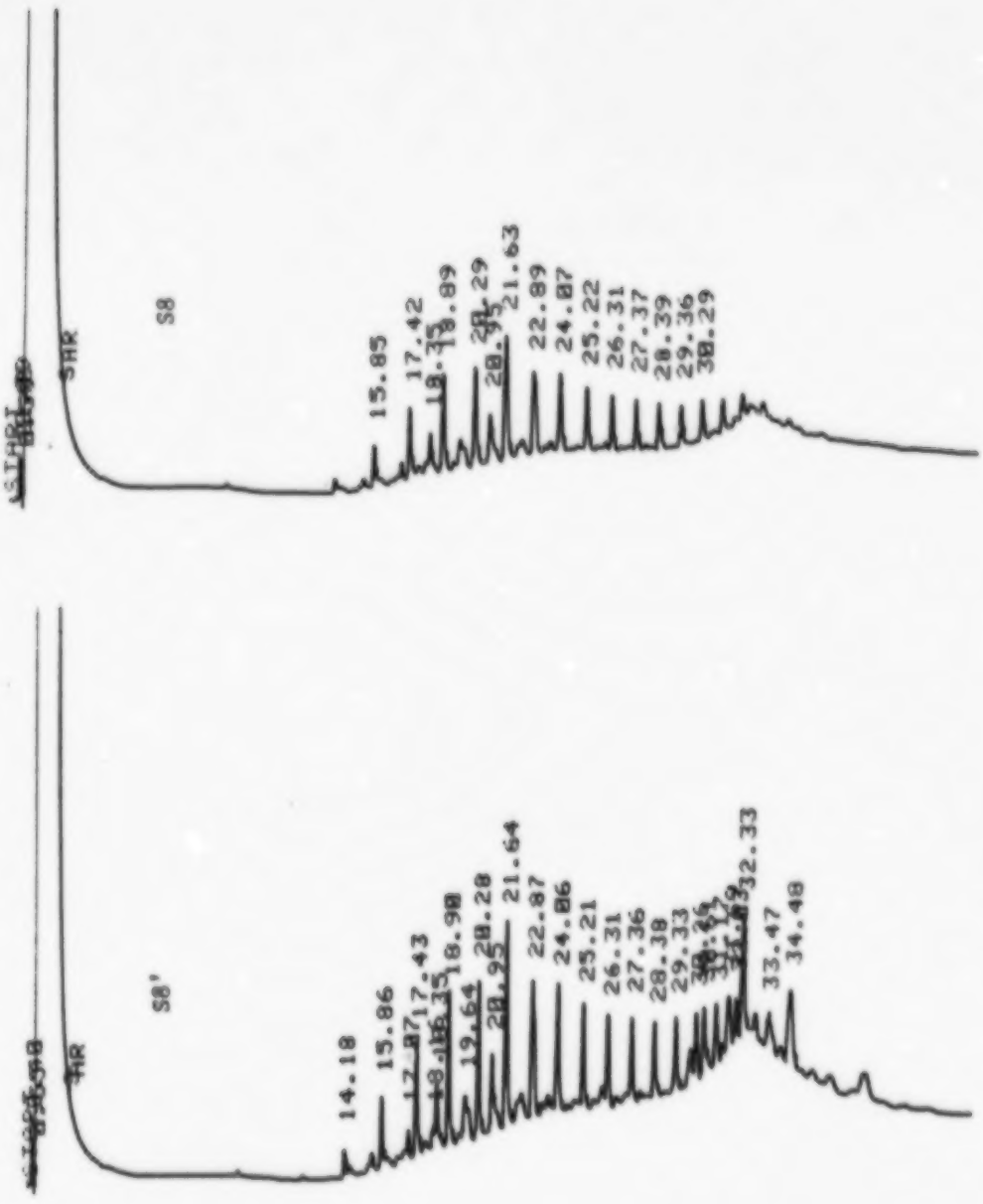
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SHR
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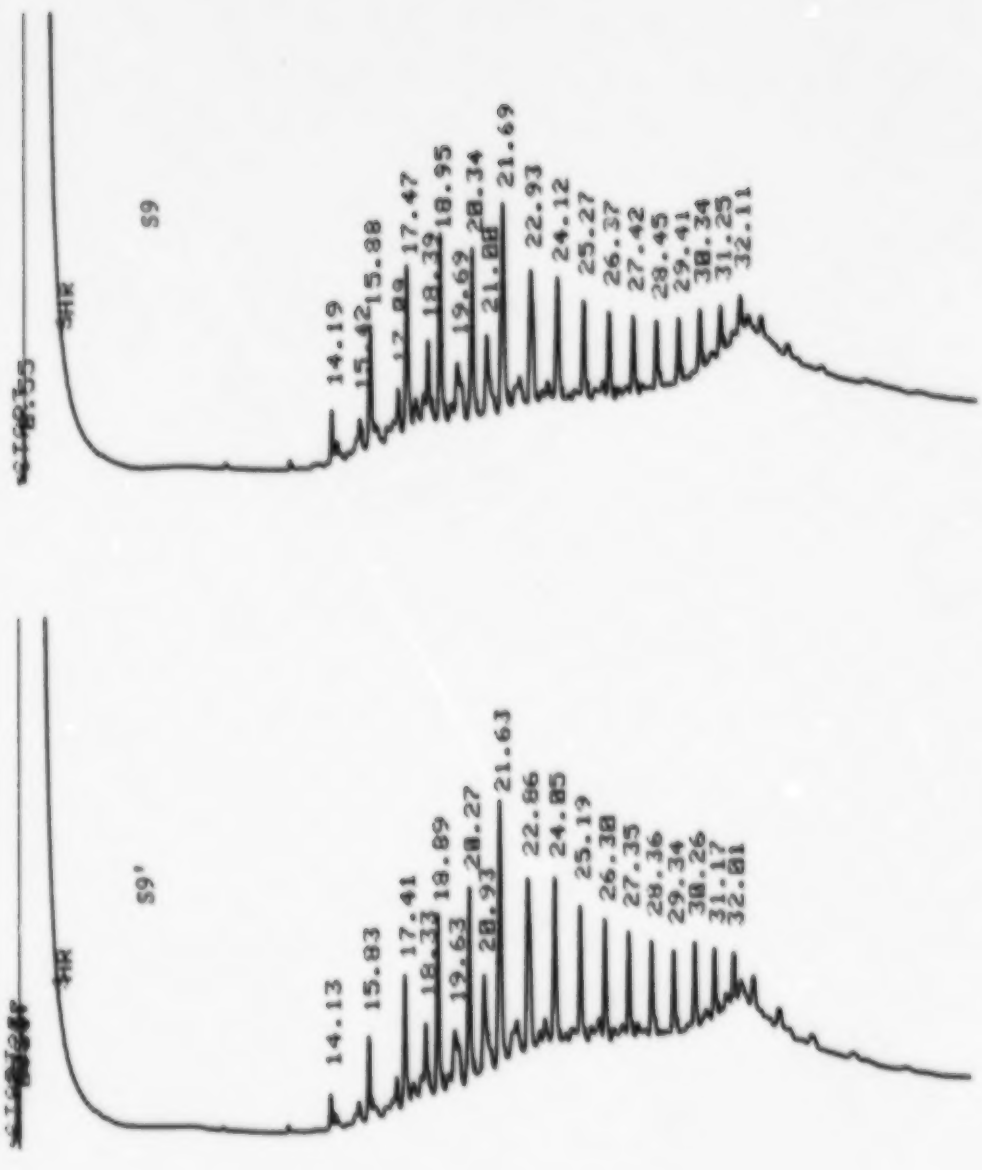
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32.11
S9'
14.13
15.83
17.41
18.13
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19.63
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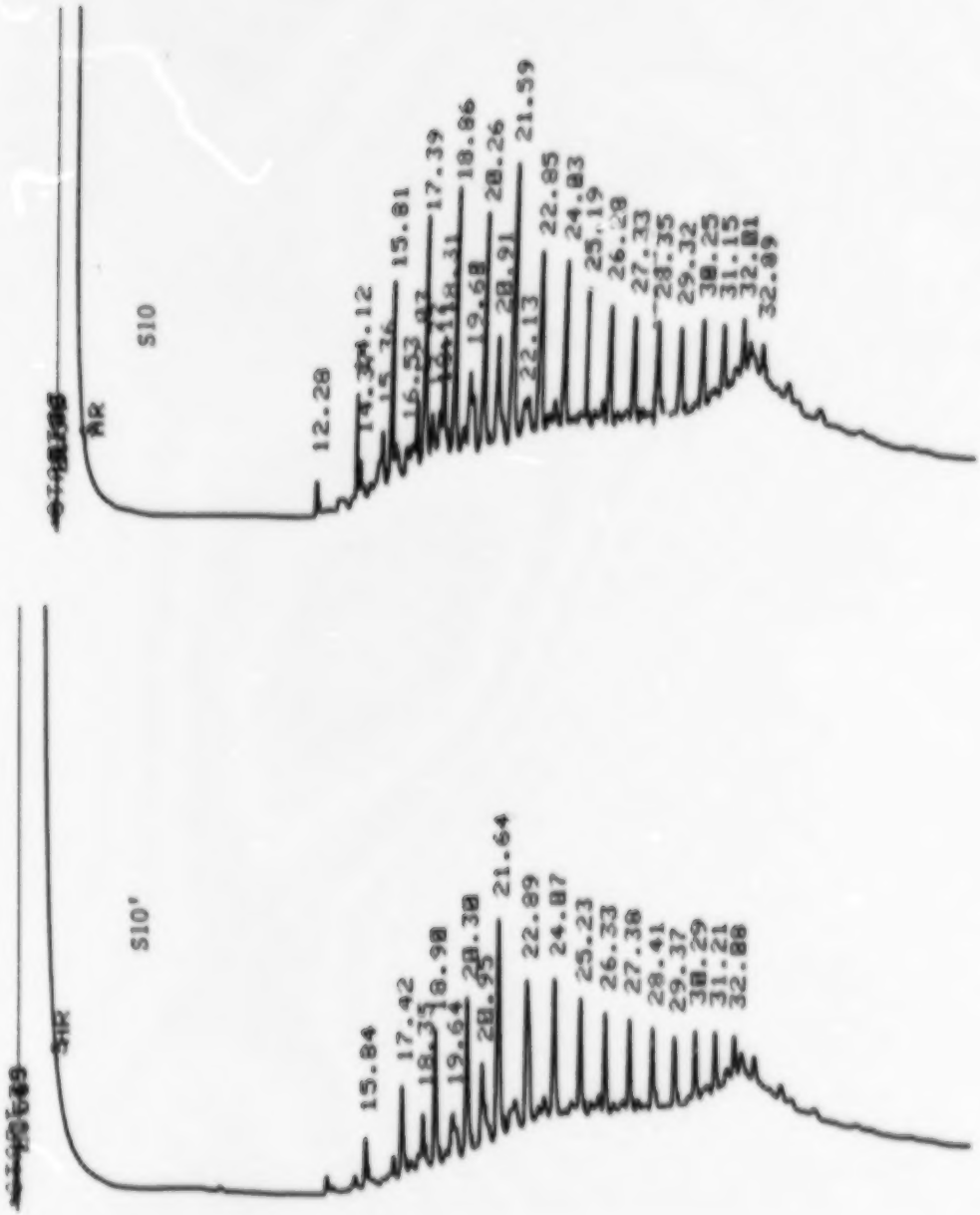
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14.12
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21.59
22.85
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25.19
26.28
27.33
28.35
29.32
30.25
31.15
32.81
32.89
S10'
SIR
15.84
17.42
18.98
19.64
20.30
21.64
22.89
24.87
25.23
26.33
27.38
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31.21
32.88

APPENDIX C - WAVERIDER DATA

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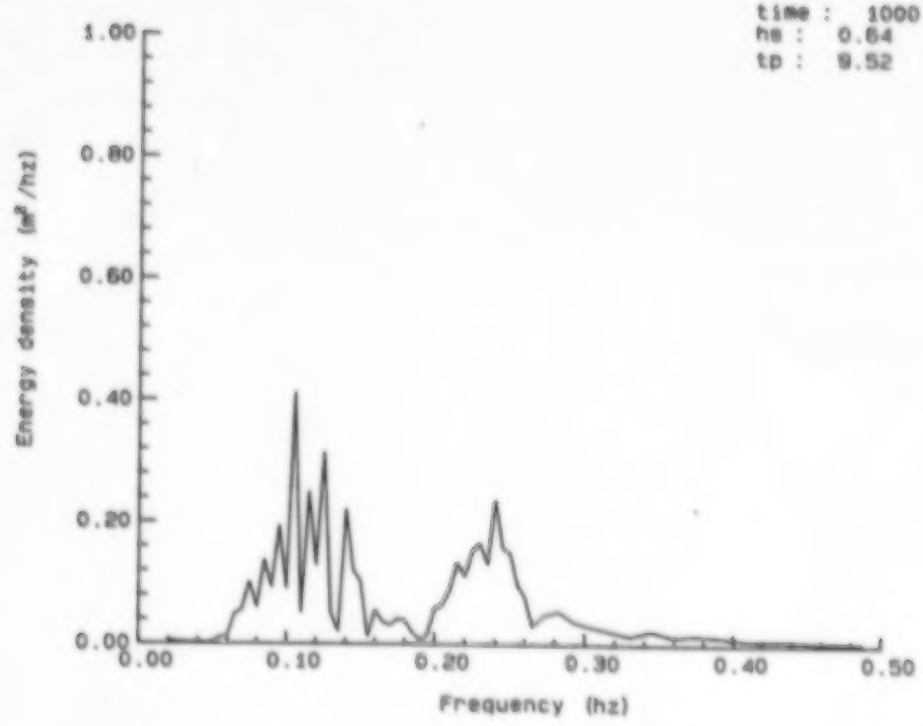

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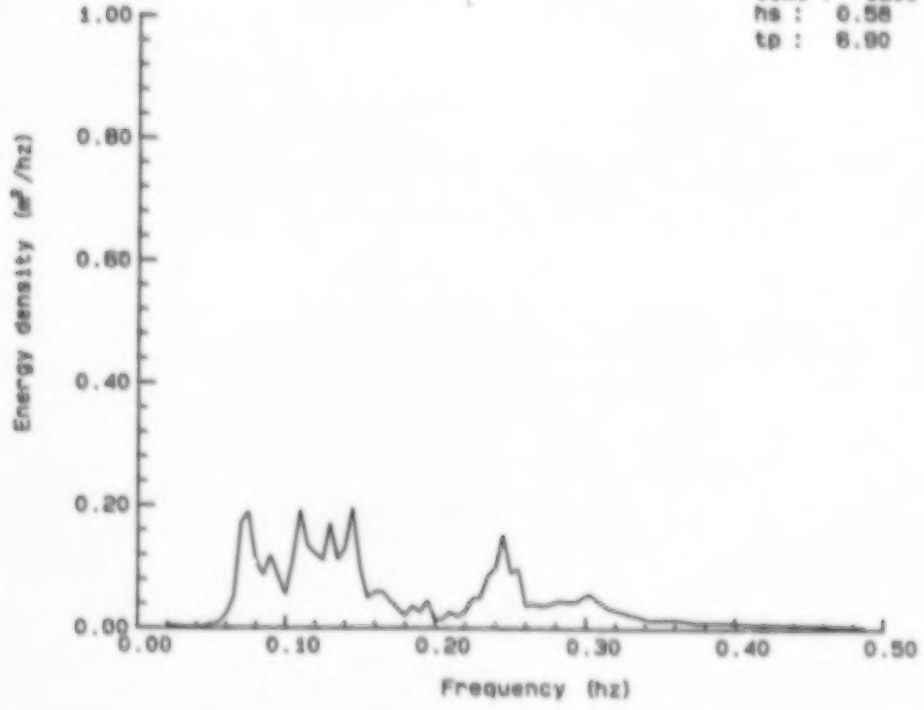

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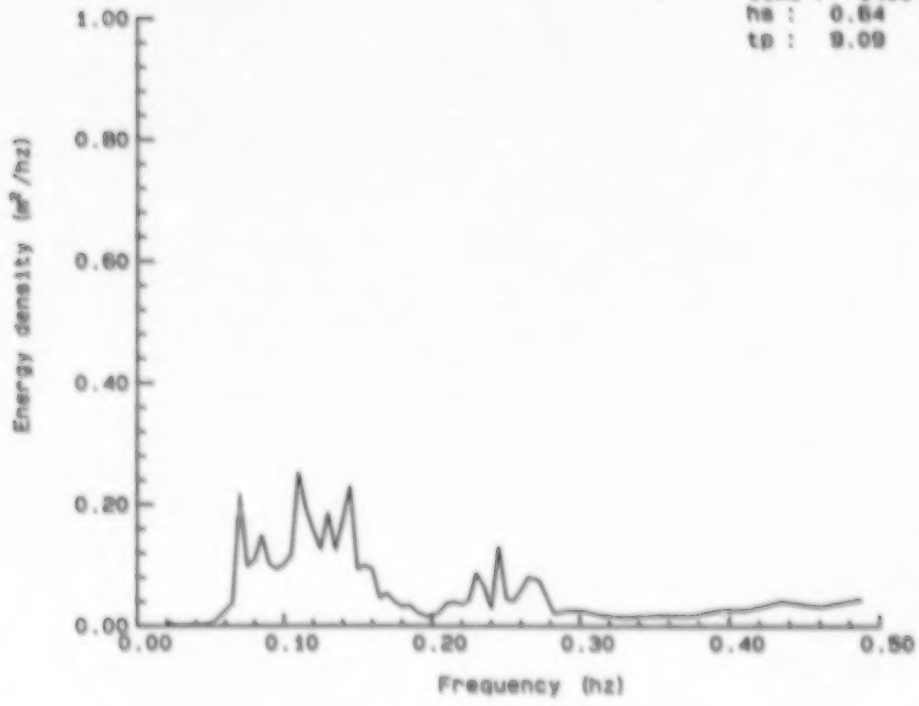

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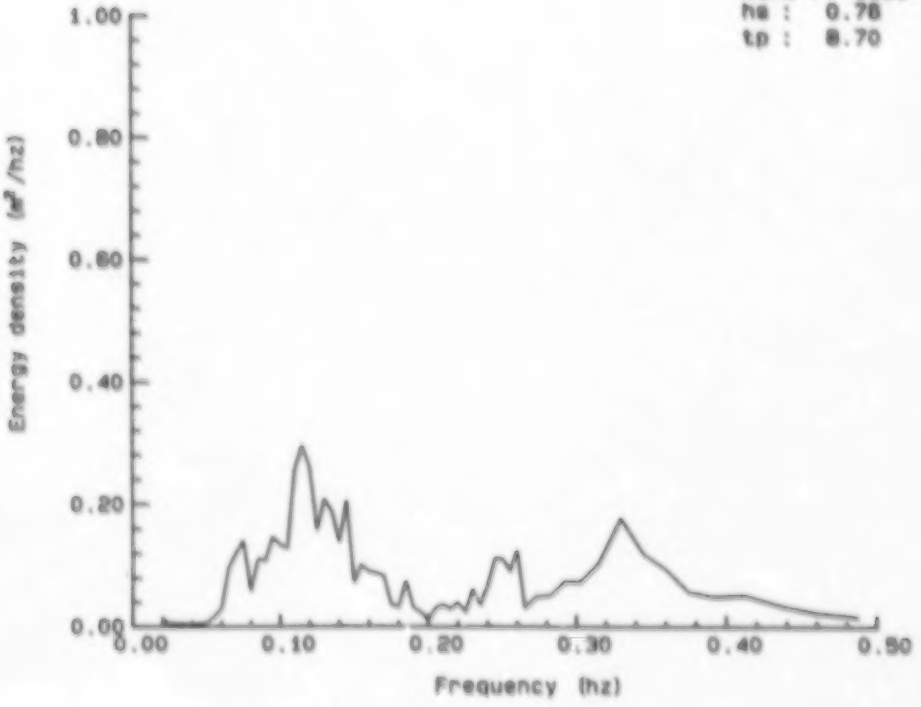
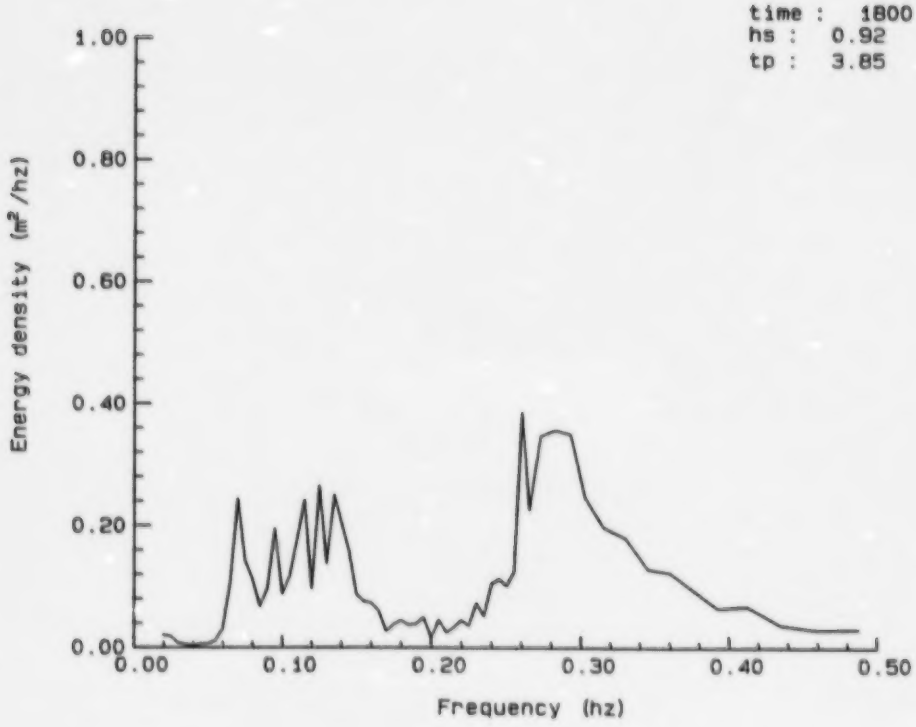
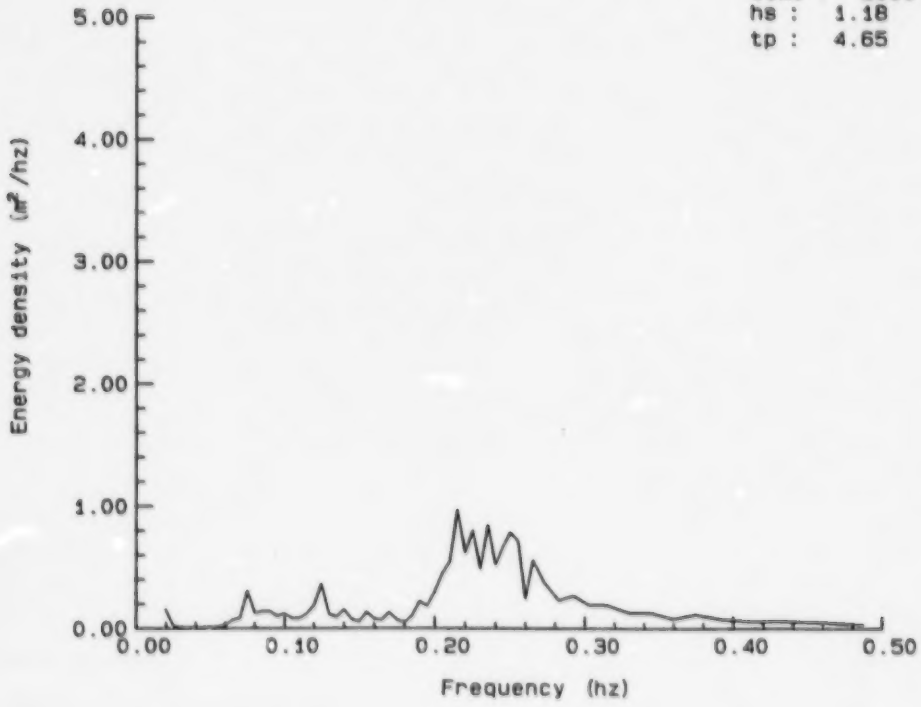
hs : 0.78
tp : 8.70



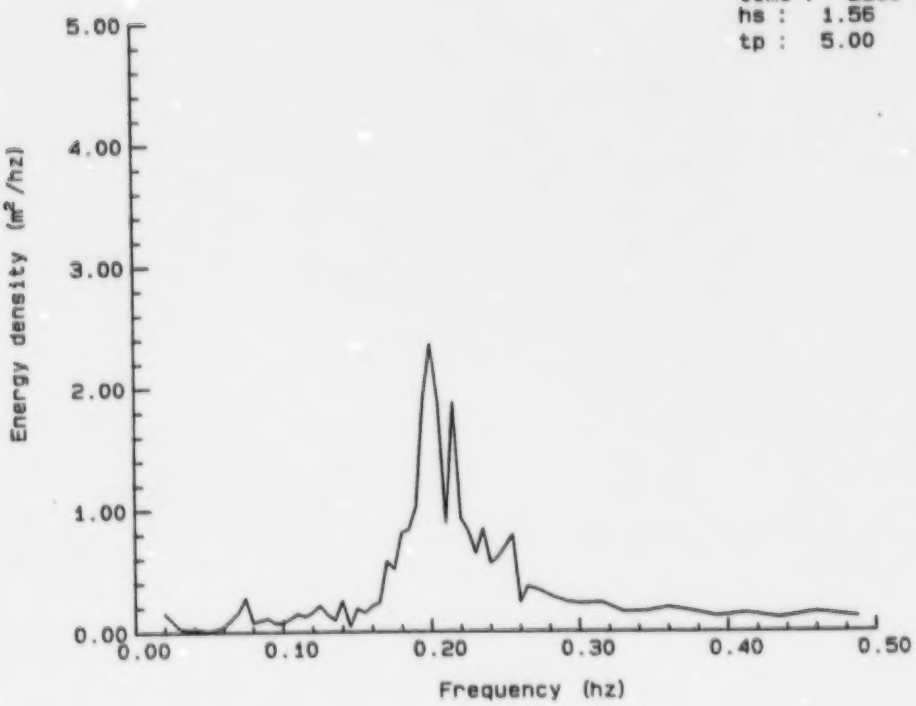
time : 1800 day : 252
hs : 0.92
tp : 3.85



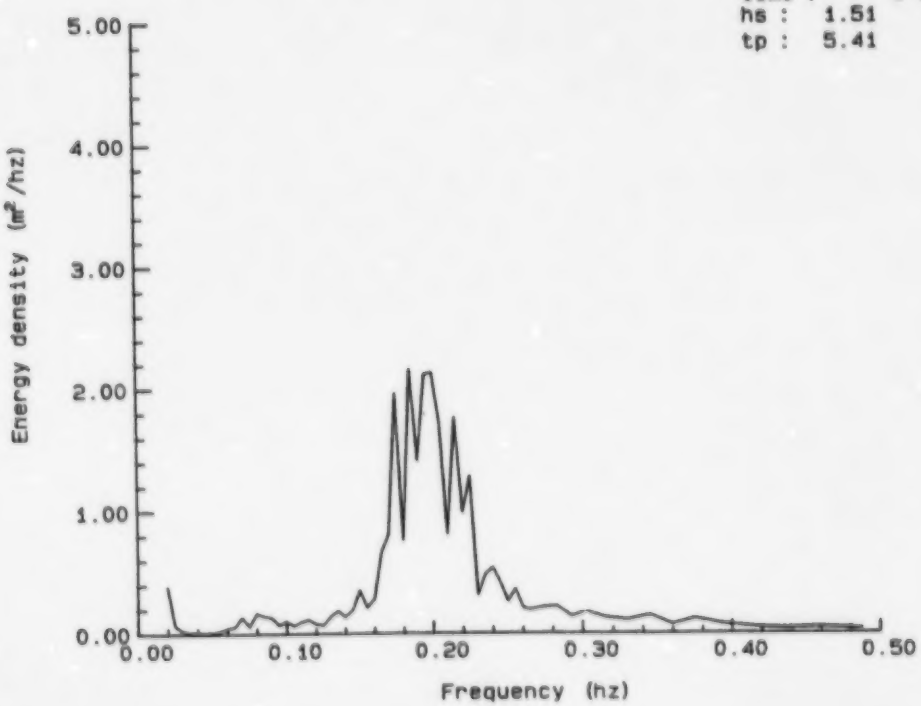
time : 2000 day : 252
hs : 1.18
tp : 4.65



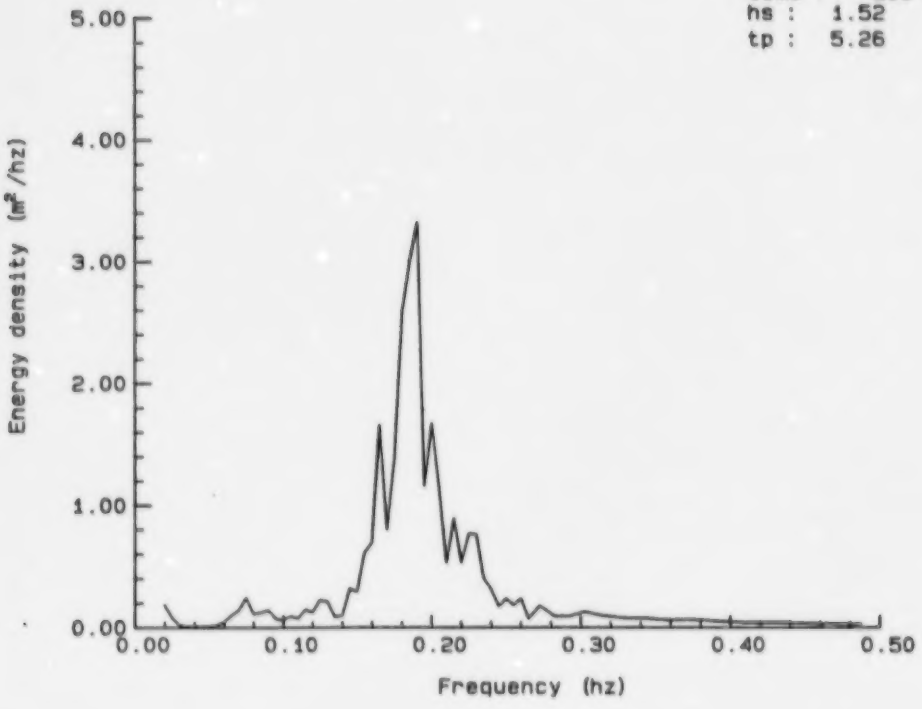
time : 2200 day : 252
hs : 1.56
tp : 5.00



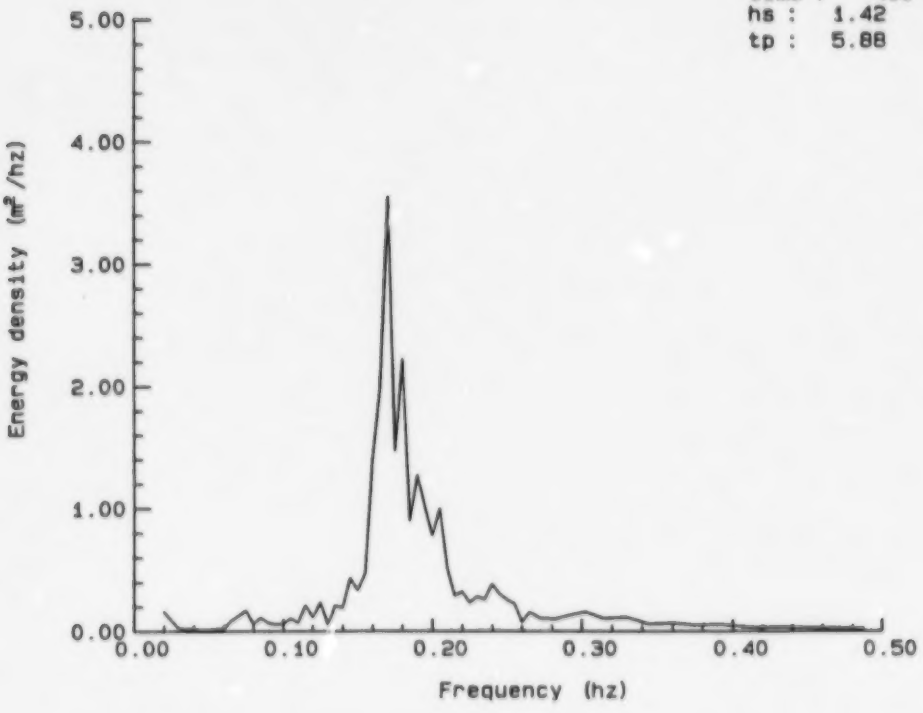
time : 0 day : 253
hs : 1.51
tp : 5.41



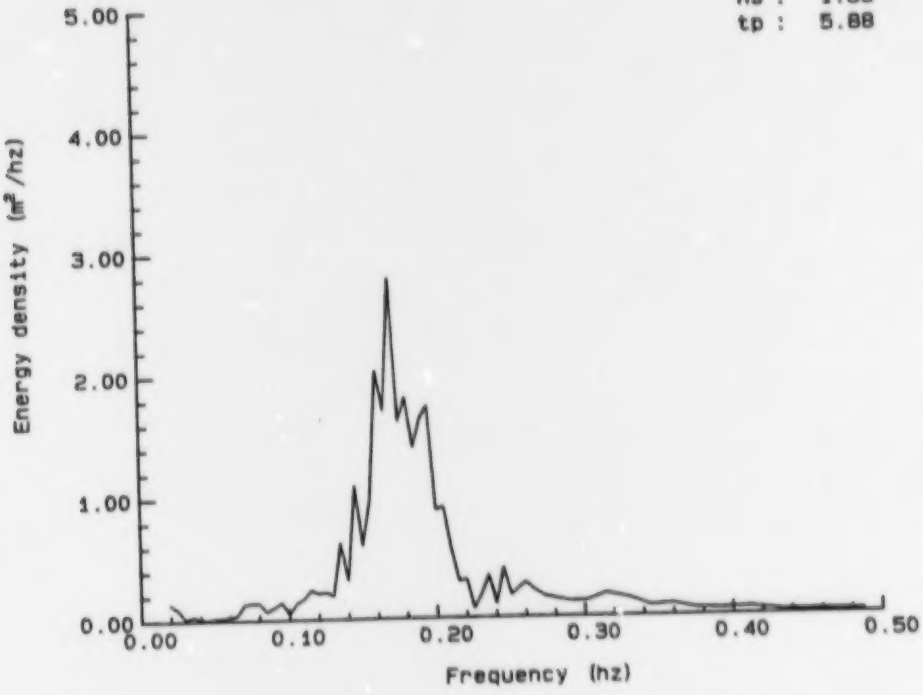
time : 200 day : 253
hs : 1.52
tp : 5.26



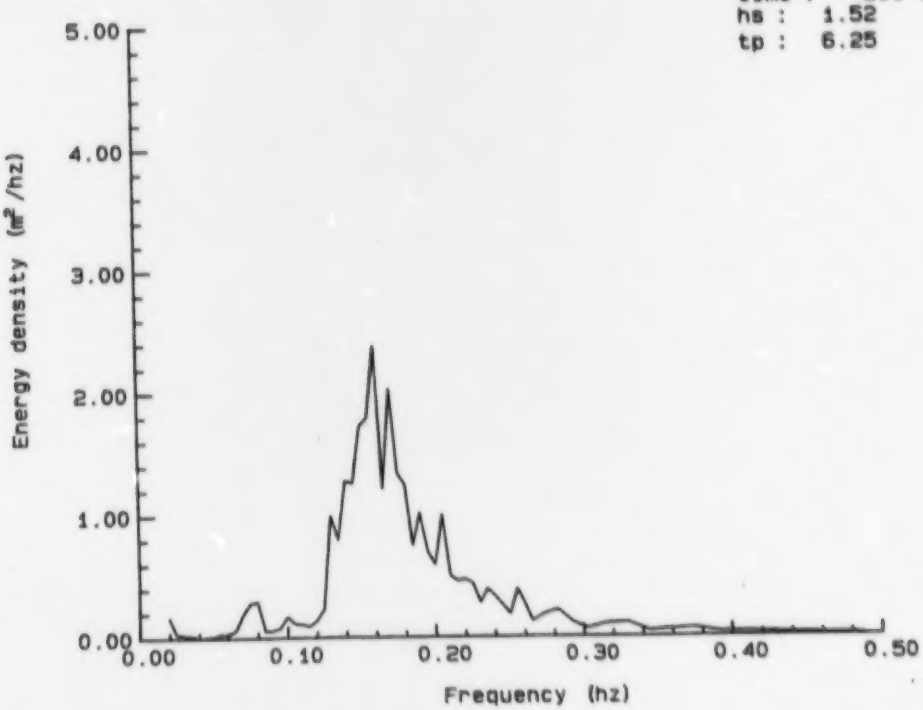
time : 400 day : 253
hs : 1.42
tp : 5.88



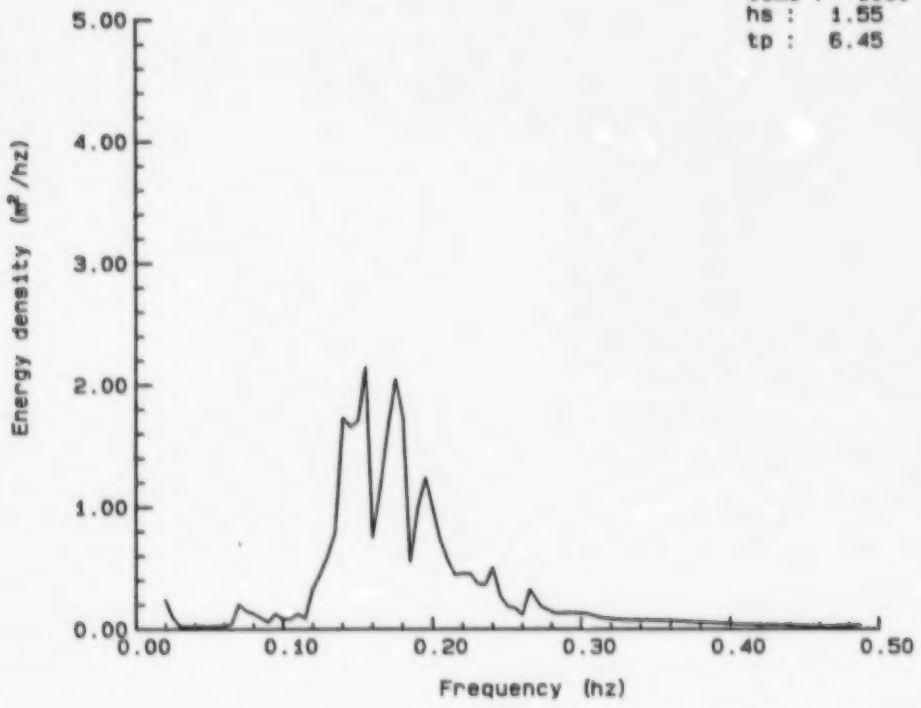
time : 600 day : 253
hs : 1.53
tp : 5.88



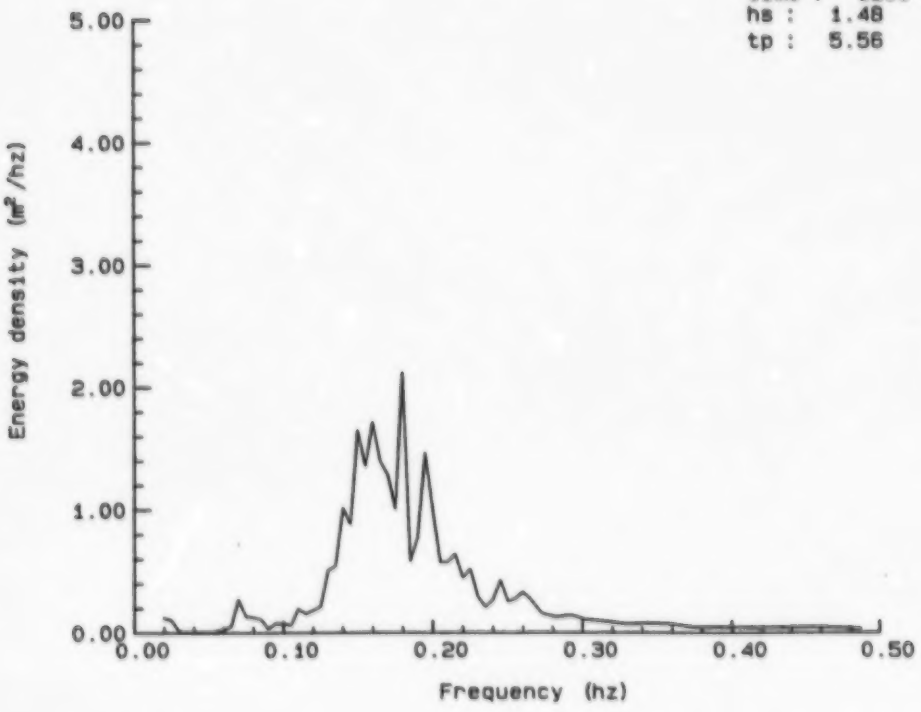
time : 800 day : 253
hs : 1.52
tp : 6.25



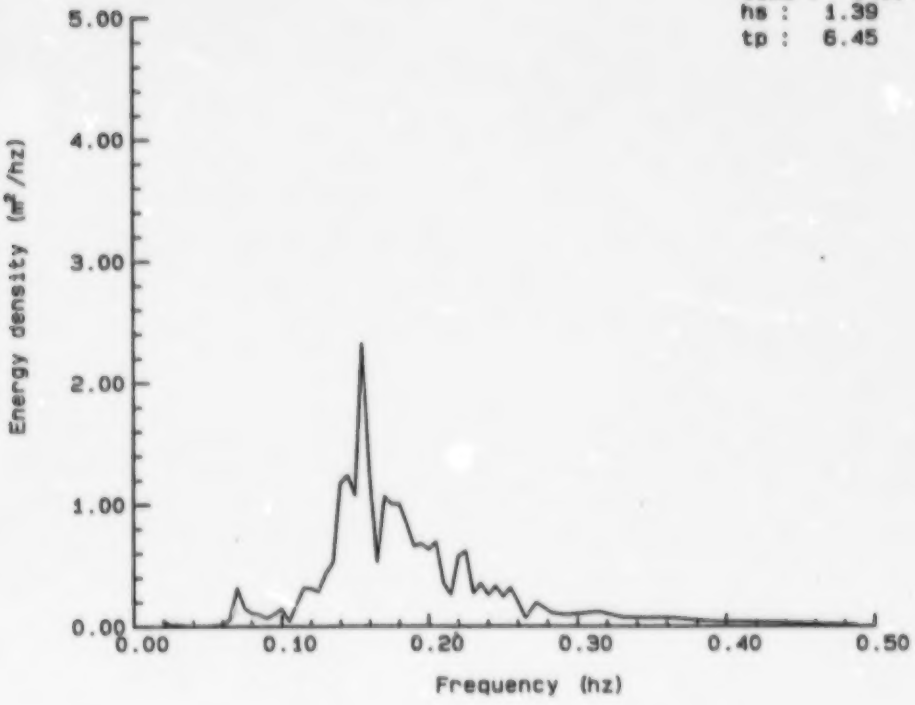
time : 1000 day : 253
hs : 1.55
tp : 6.45



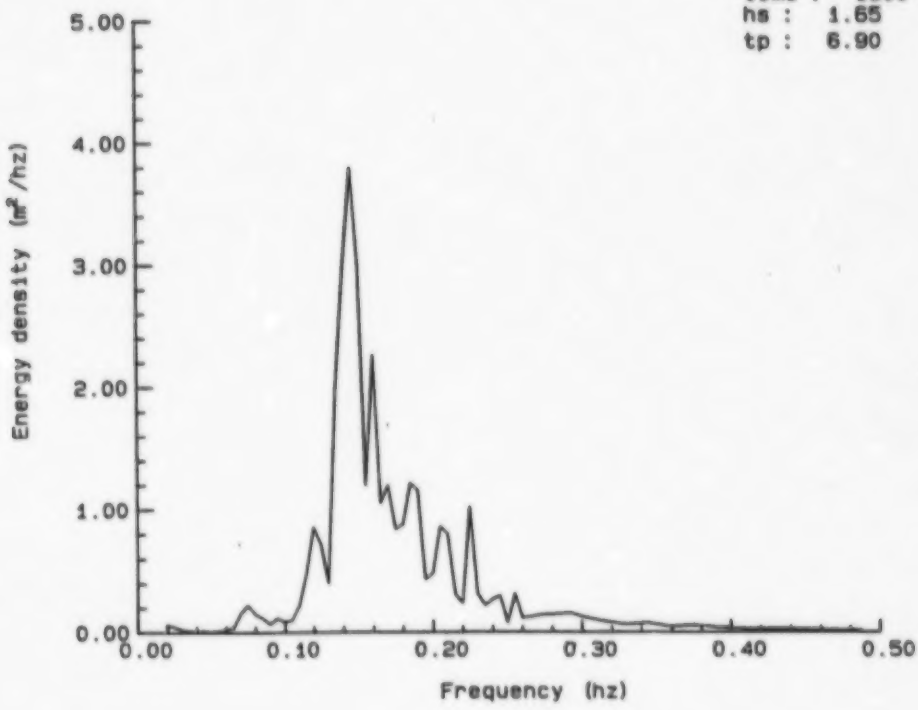
time : 1200 day : 253
hs : 1.48
tp : 5.56



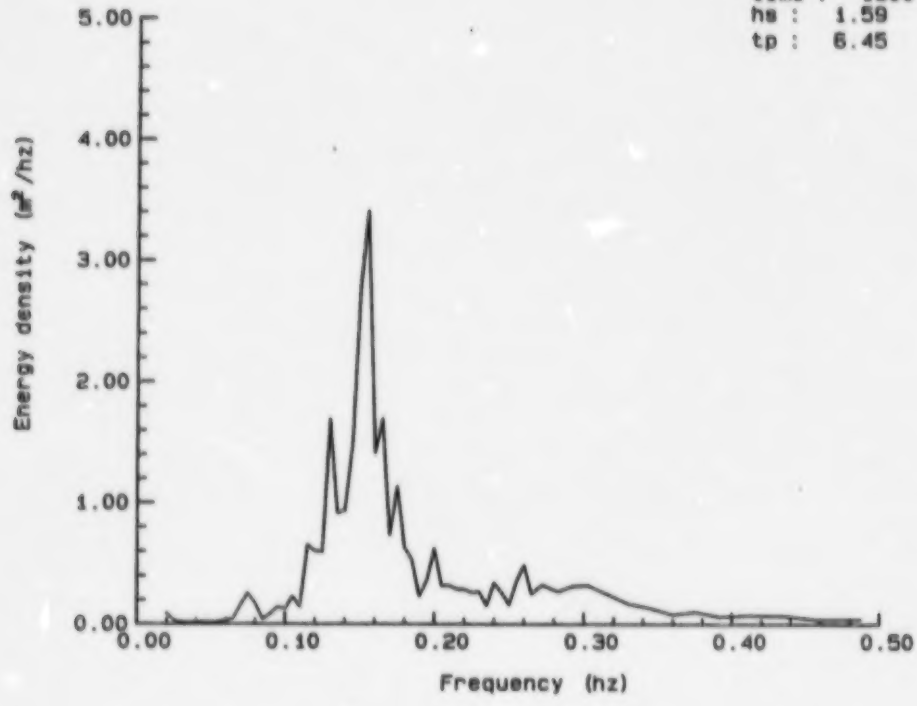
time : 1400 day : 253
hs : 1.39
tp : 6.45



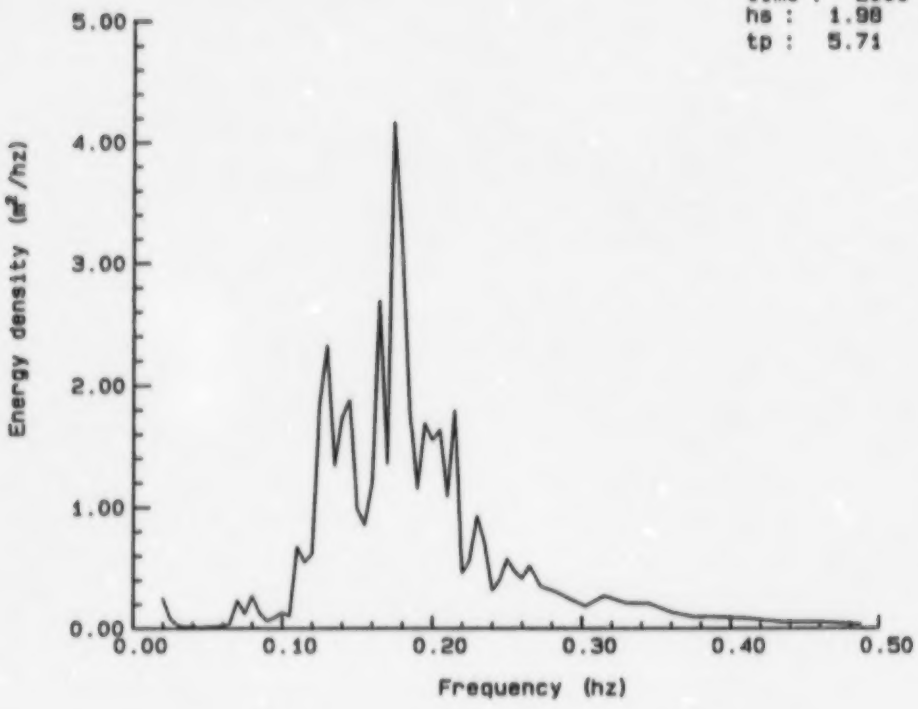
time : 1600 day : 253
hs : 1.65
tp : 6.90



time : 1800 day : 253
hs : 1.59
tp : 6.45



time : 2000 day : 253
hs : 1.98
tp : 5.71

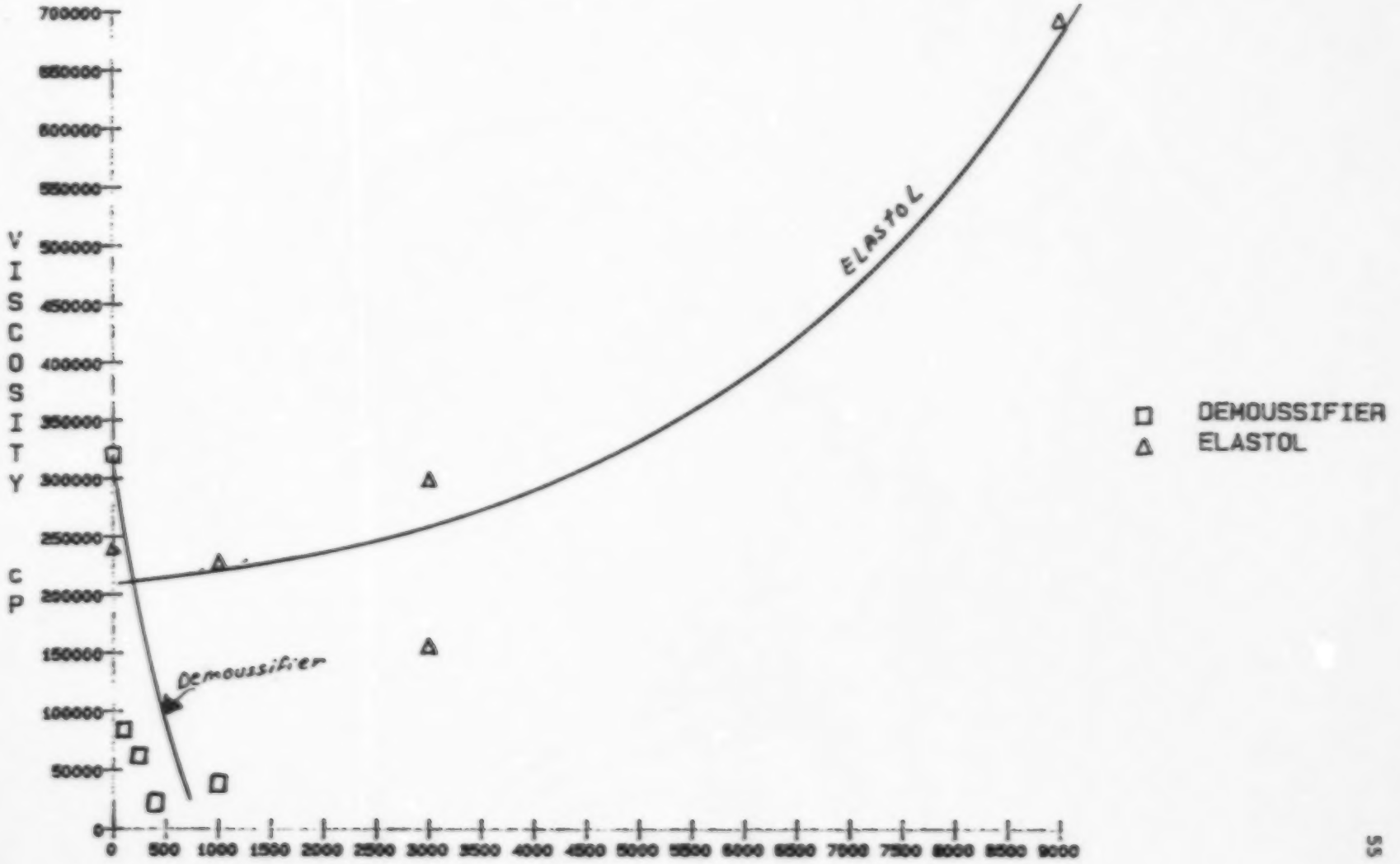


APPENDIX D - BULK TANK VOLUME VS. DEPTH

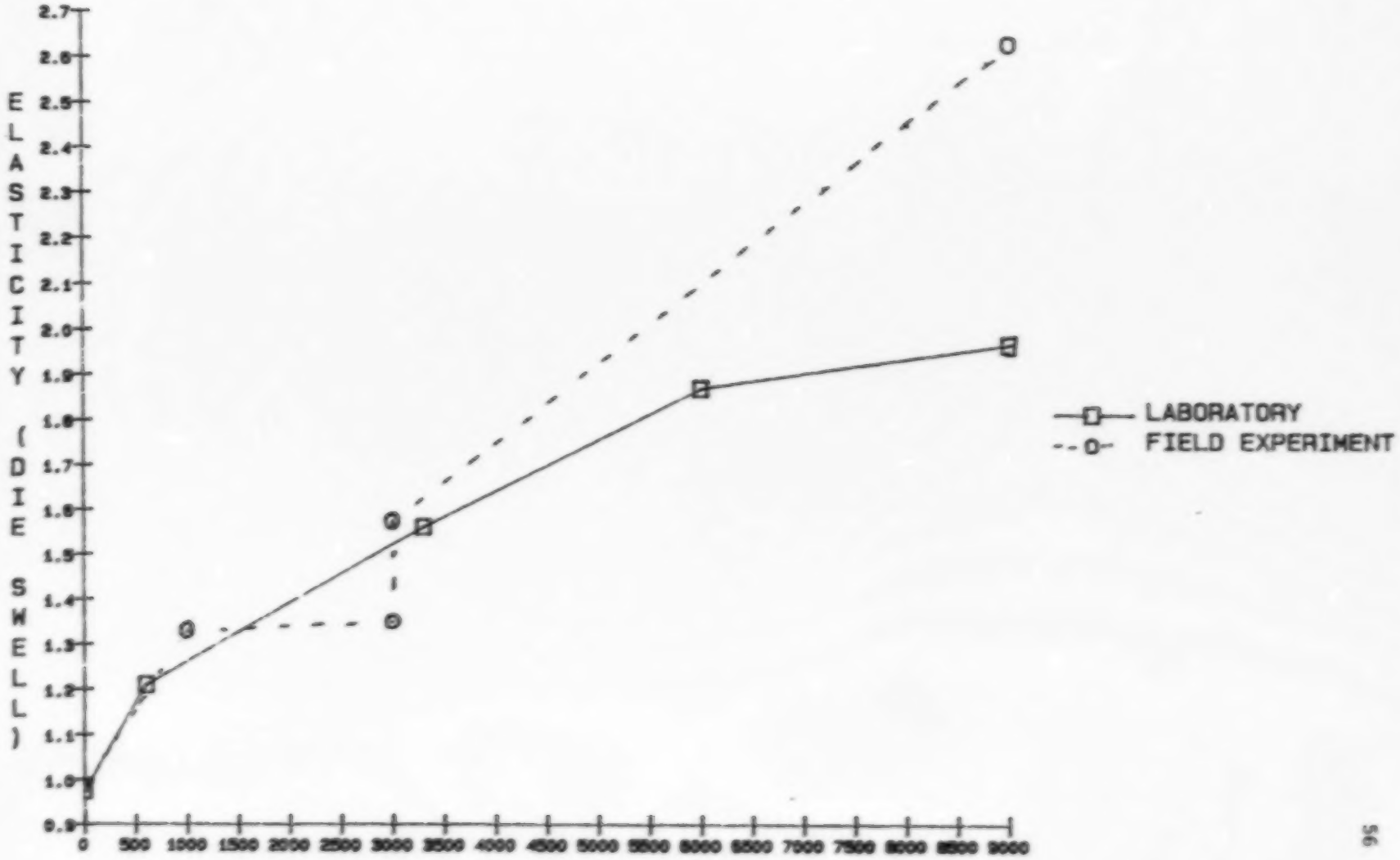
Distance from bottom		Volume	
(feet)	(inches)	cu. ft	bbl
3.5	42.0	404.0	72.2
3.4	40.8	389.3	69.5
3.3	39.6	374.7	66.9
3.2	38.4	360.0	64.3
3.1	37.2	345.4	61.7
3.0	36.0	330.8	59.1
2.9	34.8	316.3	56.5
2.8	33.6	301.8	53.9
2.7	32.4	287.5	51.3
2.6	31.2	273.2	48.8
2.5	30.0	259.1	46.3
2.4	28.8	245.0	43.8
2.3	27.6	231.2	41.3
2.2	26.4	217.4	38.8
2.1	25.2	203.9	36.4
2.0	24.0	190.5	34.0
1.9	22.8	177.3	31.7
1.8	21.6	164.3	29.3
1.7	20.4	151.6	27.1
1.6	19.2	139.1	24.8
1.5	18.0	126.9	22.7
1.4	16.8	115.0	20.5
1.3	15.6	103.4	18.5
1.2	14.4	92.2	16.5
1.1	13.2	81.3	14.5
1.0	12.0	70.8	12.6
0.9	10.8	60.7	10.8
0.8	9.6	51.1	9.1
0.7	8.4	42.0	7.5
0.6	7.2	33.5	6.0
0.5	6.0	25.6	4.6
0.4	4.8	18.4	3.3
0.3	3.6	12.0	2.1
0.2	2.4	6.5	1.2
0.1	1.2	2.3	0.4

APPENDIX E - RAW SHIPBOARD DATA

VISCOSITY OF ALL SLICKS AFTER 5 HOURS



COMPARISON OF ELASTOL IN THE FIELD AND THE LAB



DEMOUSSIFIER TRIALS

SLICK	TREATMENT	SAMPLE 1 TIME	VISCOSITY	WATER CONTENT	COMMENTS	SAMPLE 2 TIME	VISCOSITY	WATER CONTENT	COMMENTS
1	1000-PPM	60	10000	84%	NO MOUSSE FORMED	300	84250	90%	NO MOUSSE NOTED
2	250-PPM	60	2700	54%	NO MOUSSE FORMED	300	62250	93%	NO MOUSSE NOTED
3	CONTROL	60	6350	88%	HEAVY MOUSSE	270	320000	95%	HEAVY MOUSSE
4	POST-4000PPM	60	2200	72%	MODERATE MOUSSE	PRE-240	105000	90%	HEAVY MOUSSE
						POST-270	22600	78%	TREATMENT BROKE MOUSSE
5	PRE-1000PPM	15	970	32%	NO MOUSSE OBSERVED	280	38500	80%	NO MOUSSE FORMED

ELASTOL TRIALS

SLICK	TREATMENT	SAMPLE 1 TIME	VISCOSITY	ELASTICITY	COMMENTS	SAMPLE 2 TIME	VISCOSITY	ELASTICITY	COMMENTS
6	3000-PPM	130	29300	1.33	MODERATELY ELASTIC	280	300000	1.35	HIGHLY ELASTIC
7	1000-PPM	145	32250	1.28	LOW ELASTICITY	280	228000	1.33	MODERATLEY ELASTIC
8	CONTROL	135	187000	0.99	NO ELASTICITY,WIDESPREAD	290	242000	0.99	NO ELASTICITY,WIDESPREA
9	9000-PPM	120	93000	1.99	HIGH ELASTICITY	330	696000	2.63	SUPER ELASTIC
10	PRE-3000PPM	115	170500	1.35	MODERATE ELASTICITY	315	156000	1.57	HIGHLY ELASTIC

DAY 1 SEPTEMBER 9 DEMOUSSIFIER TRIAL

SLICK	TREATMENT	SLICK LAYING TIME LAID	SLICK LAYING POSITION LAID	PUMP ON TIME	WIND DIRECTION	WIND SPEED	AIR TEMP	SWELL HEIGHT	CHOP HEIGHT	OTHER WEATHER OBSERVATIONS	SAMPLE 1 SAMPLE TIME	ELAPSED TIME	SLICK POSITION
1	1000-PPM	9.09	44:14:36 61:49:41	9	110	6	19	0.1	0.02	FOGGY	10:09	60	SAME
2	250-PPM	9:23	44:13:46 61:48:38	5	110	6	19	0.1	0.02	FOG	10:23	60	SAME
3	CONTROL	9:39	44:12:70 61:47:32	5	110	6	19	0.1	0.02	FOG	10:39	60	SAME
4	POST-4000PPM	11:25	44:12:02 61:46:24	4	120	10	18	0.2	0.04	FOGGY	12:25	60	SAME
5	PRE-1000PPM	11:40	44:11:11 61:45:21	3	120	10	18	0.2	0.04	FOGGY	11:50	15	SAME

DAY 2 SEPTEMBER 10 ELASTOL TRIALS

SLICK	TREATMENT	SLICK LAYING TIME LAID	SLICK LAYING POSITION LAID	PUMP ON TIME	WIND DIRECTION	WIND SPEED	AIR TEMP	SWELL HEIGHT	CHOP HEIGHT	OTHER WEATHER OBSERVATIONS	SAMPLE 1 SAMPLE TIME	ELAPSED TIME	SLICK POSITION
6	3000-PPM	12:48	44:13:03 61:45:05	5	290	12	17	2	0.03	FOGGY	15:04	130	44:12:51 61:44:70
7	1000-PPM	13:05	44:14:01 61:44:20	5	305	8	17	2	0.03	FOGGY	15:25	145	44:13:96 61:44:83
8	CONTROL	13:22	44:15:16 61:43:34	4	305	10	17	2	0.03	FOGGY	15:37	135	44:15:14 61:44:30
9	9000-PPM	13:47	44:14:40 61:42:38	5	305	10	17	2	0.03	FOGGY	15:49	120	44:16:19 61:43:19
10	PRE-3000PPM	14:13	44:17:51 61:41:33	4	305	10	17	2	0.03	FOGGY	15:59	115	44:17:13 61:42:04

NOTES ALL DATA ARE OBSERVATIONS FROM THE BRIDGE OR FROM ON-BOARD ANALYSIS HAVE INFORMATION WILL CHANGE WHEN WAVERIDER DATA IS ANALYZED
PURPOSE OF THIS TABLE IS TO PROVIDE ALL BRIDGE AND ANALYTICAL DATA TO THE REPORT WRITERS AND TO THE EXPERIMENTS SO THAT THEY HAVE IMMEDIATE DAT

SAMPLING DURATION	WIND DIRECTION	WIND SPEED	AIR TEMP	SWELL HEIGHT	CHOP HEIGHT	OTHER WEATHER OBSERVATIONS	ANALYSIS TIME	VISCOSITY	WATER CONTENT	OBSERVATIONS	SAMPLE 2 SAMPLE TIME	ELAPSED TIME
?	115	8	10	0.1	0.02	FOG	11:05	10080	84%	NO MOUSSE NOTED	13:56	300
											SAMPLE 3 9:45	SEPTEMBER 1475
?	115	8	10	0.1	0.02	FOG	10:24	2790	54%	NO MOUSSE NOTED	14:13	300
											SAMPLE 3 9:48	SEPTEMBER 1460
?	115	8	10	0.1	0.02	FOG	11:25	6350	88%	LARGELY MOUSSE	14:46	270
											SAMPLE 3 10:00	SEPTEMBER 1460
?	130	13	10	0.4	0.05	FOGGY	11:40	2200	72%	MOUSSE PATCHES	15:24	240
											16:05	270
?	130	13	10	0.4	0.05	FOGGY	11:55	970	32%	NO MOUSSE NOTED	16:20	280

SAMPLING DURATION	WIND DIRECTION	WIND SPEED	AIR TEMP	SWELL HEIGHT	CHOP HEIGHT	OTHER WEATHER OBSERVATIONS	ANALYSIS TIME	VISCOSITY	ELASTICITY DIE-SWELL	OBSERVATIONS	SAMPLE 2 SAMPLE TIME	ELAPSED TIME
0	305	12	17	2	0.02	FOGGY	15:20	25300	1.33	MODERATELY ELASTIC	17:36	280
?	305	20	17	2.5	0.08	FOGGY	15:39	37250	1.28	MODERATELY ELASTIC	17:36	280
3	305	20	17	2.5	0.08	FOGGY	15:47	187000	0.99	SOME MOUSSE	18:11	290
10	305	25	17	2.5	0.08	FOGGY	16:10	93000	1.99	HIGHLY ELASTIC	19:16	330
?	305	25	17	2.5	0.08	FOGGY	16:20	170500	1.35	MODERATELY ELASTIC	19:20	315

TIME IS IN MINUTES VISCOSITY IS IN cP TIME OF SAMPLING AND PUMPING ARE TAKEN FROM BRIDGE OBSERVATIONS AND MAY NOT BE ACCURATE
PLEASE NOTE THE UPDATES THAT WILL BE MADE FROM OTHER SOURCES NOTE THAT FOR THE

SLICK POSITION	SAMPLING DURATION	WIND DIRECTION	WIND SPEED	AIR TEMP	SWELL HEIGHT	CHOP HEIGHT	OTHER WEATHER OBSERVATIONS	ANALYSIS TIME	VISCOSITY cP	WATER CONTENT	OBSERVATIONS
13760 29342	18	130	13	18	0.2	0.04	FOG	14:20	84250	90%	NO MOUSSE EVIDENT
10											
44:15:21 61:46:58	3	290	12	17	3	0.03	FOG	9:45	592000	?	PROB. BILGE WASTE
44:12:54 61:49:13	?	130	13	18	0.2	0.04	FOG	14:20	62250	93%	NOT MOUSSE
10											
44:14:41 61:46:24	NONE	290	12	17	3	0.03	FOG	NONE	NONE	NOT DONE	SHEEN ONLY IN AREA
44:12:27 61:49:10	?	130	13	18	0.2	0.04	FOGGY	15:00	320000	95%	STABLE MOUSSE
10											
44:13:44 61:44:14	NONE	290	12	17	3	0.03	FOG	NONE	NONE	NOT DONE	BUOYS ONLY FOUND
44:11:56 61:48:12	?	130	13	18	0.2	0.03	FOGGY MOUSSE	15:31	105000	90%	PRE-TREATMENT
	?						AFTER TREATMENT	16:00	22600	78%	POST-TREATMENT
44:11:28 61:48:21	?	130	18	16	0.6	0.08	FOGGY	16:15	38500	80%	NO MOUSSE NOTED

SLICK POSITION	SAMPLING DURATION	WIND DIRECTION	WIND SPEED	AIR TEMP	SWELL HEIGHT	CHOP HEIGHT	OTHER WEATHER OBSERVATIONS	ANALYSIS TIME	VISCOSITY cP	ELASTICITY DIE SWELL	OBSERVATIONS
44:12:23 61:45:87	14	45	25	16	3	0.2	HIGH SEAS	17:60	300000	1.35	HIGHLY ELASTIC
44:13:09 61:46:33	5	45	25	16	3	0.2	HIGH SEAS	18:00	220000	1.33	MODERATELY ELASTIC
44:14:56 61:46:16	5	45	25	16	3	0.2	HIGH SEAS	18:20	242000	0.99	NOT ELASTIC,WIDESPREAD
44:15:24 61:45:42	4	45	28	16	3.5	0.2	BEAUFORT 6	9:15 ND	696000	2.63	SUPER ELASTIC
44:15:96 61:45:31	6	45	28	16	3.5	0.2	BEAUFORT 6	9:45 ND	156000	1.57	HIGHLY ELASTIC

WIND DIRECTIONS AND SPEEDS ARE FROM THE SHIPS LOG AND ARE INTERPOLATED ND= NEXT DAY
DEMOUSSIFIER TRIALS , SAMPLING WAS ATTEMPTED ON THE SECOND DAY AND THIS DAY IS ROLLED IN WITH SAMPLE 2 DATA